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# PROPULSION AND VEHICLE ENGINEERING LABORATORY

## MONTHLY PROGRESS REPORT

For Period

July 1, 1968, Through July 31, 1968

**FOR INTERNAL USE ONLY**

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-68-7

# MONTHLY PROGRESS REPORT

(July 1, 1968, Through July 31, 1968)

By

Materials Division
Advanced Studies Office
Vehicle Systems Division
Structures Division
Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

R-P&VE-M-68-7

JULY 1, 1968 THROUGH JULY 31, 1968

## SATURN IB

### S-IB Stage

Evaluation of Heat Shield Insulation Materials

A second experimental heat shield produced by the Stresskin Products Company was installed and tested during the short duration firing of S-IB-12. This panel consisted of a welded honeycomb base structure insulated with a blanket of Refrasil A-100 enclosed in Inconel foil. The experimental panel was located in position 4 between fins 1 and 4. Post test examination revealed at least 17 cracks, 3/4-inch in length or shorter, in the outer layer of the Inconel foil. The same Stresskin panel will be tested again during the long duration static firing of S-IB-12, which is tentatively scheduled on July 25.

## SATURN V

### I. S-IC Stage

A. Evaluation of Commercial Adhesives

Studies are continuing as outlined below to develop or modify high performance adhesive systems for use on Saturn V stages.

1. Investigation of the Effect of Bondline Thickness on Lapshear Tensile Strength of Polyurethane Adhesive

The bondline thickness of bonded adhesive specimens prepared in this division is conventionally controlled by incorporation of glass beads into the adhesive mix. A study has been completed recently in which a variety of bead size ranges were used to establish bondline thickness to determine the effect of bondline thickness in lapshear strength at room temperature. The bead diameter ranges and corresponding lapshear tensile strengths were as follows:

| Bead Diameter (Mils) | Lapshear Tensile Strength (psi) |
|---|---|
| 0.4-1.1 | 2322 |
| 1.7-2.4 | 2208 |
| 2.4-3.5 | 2196 |
| 3.5-4.9 | 2196 |
| 4.9-6.9 | 1770 |
| 6.9-9.7 | 1522 |
| 9.7-14 | 1216 |
| 14-20 | 1060 |
| 20-30 | 976 |

The adhesive used in these tests was 7343/7139 (100 g./11.5 g.) cured 24 hours at room temperature, 24 hours at 160°F (71°C). Size range 3.5-4.9 mils is standard for most adhesive tests in this laboratory and from these results appears to offer an acceptable bondline thickness control.

2. Investigation of the Effects of Long-Term Aging on Bond Strength of Polyurethane Adhesive

Specimens bonded with Narmco 7343/7139 under contract NAS8-11958 for long-term aging were tested after 18 months ambient outdoor storage. Results of lapshear tensile and Bell peel determinations show strengths after 18 months almost equivalent to strengths obtained in the initial control sets tested one month after fabrication, before outdoor exposure was initiated. This was true both for the silane primed specimens containing silane coupling agents in the adhesive mix and for the unprimed control specimens with no silane coupling agent in the adhesive mix. Results from some of the previous periodic tests have shown definite strength loss for the latter type specimens, those prepared without silane coupling agents, while other tests, such as this one, have indicated recovery from those temporary weaknesses. Variation of bond strength with seasonal humidity remains the most reasonable explanation advanced to date for this behavior.

3. Investigation of the Effects of High Humidity on Polyurethane Adhesive Bond Strength

Aluminum lapshear tensile specimens primed with a Stafoam AA-1802 primer formulation and bonded with the Narmco 7343/7139 polyurethane adhesive system have been fabricated for aging over a period of several months in ambient laboratory environment and at 100 percent humidity (in a closed vessel over water). Both adhesive and primer formulations were prepared with and without silane agent additives. The Stafoam AA-1802 primer system has been shown to improve strengths of bonds made with Narmco 7343/7139, but information on aging characteristics has not been available. First results will be reported after one month aging has been completed for all specimens.

B. Development and Evaluation of Potting Compounds and Conformal Coatings

A Raybestos-Manhattan material, designated 3550, is being evaluated for conformal coating applications. This formulation is a solvent-based, asbestos-filled fluorocarbon polymer having a very low order of flammability in oxygen-enriched environments. The material, supplied in the form of a thixotropic paste, was processed by pressing into a mold and allowing the solvent to evaporate at 77°F (25°C). The coating material was then heated for 24 hours at 160°F (71°C) and cooled in a dessicator prior to fabrication of dielectric test specimens. These specimens have been submitted for appropriate dielectric measurements.

A review was made of Marquardt Corporation Materials Specification MMS-2505, which this company suggested as a substitute for the MSFC potting specification 22B in certain limited applications. Appropriate comments were forwarded.

C. Investigation of Cleaning Procedures

Work continued on the evaluation of Diversery 9-333 product for descaling and polishing stainless steel. Several panels of 304 stainless steel were treated by the Diversery method and several panels of this alloy were electroplated for a direct comparison of the two methods. The panels showed about the same degree of brightness, but the electropolished panels showed considerably more "leveling" of the surface than did the Diversery 9-333 treated panels. Panels of 304 stainless steel, contaminated with iron particles and then either electropolished or treated in the Diversery product, are still in salt spray test to determine the passivation effects of the Diversery 9-333 product. After about a month in the salt spray environment, both panels show about the same amount of rust. In both cases, most of the rust appears to have formed at the top of the panels and run down toward the bottom of the panels. Only a small amount of rust appears to have started in the area of initial contamination.

Specimens of 2219 and 2014 aluminum alloys have a mossy corrosion growth after approximately three and a half months of exposure to samples of Dowclene IVR with excess added water. This confirms earlier test results which had been reported several months ago. Although the same amount of water had been added to both Freon PCA and trichloroethylene, no appreciable changes have been noted on alloys exposed to these materials. This indicates that for the material (Dowclene IVR) to be suitable for use as a precision cleaning material, the water content must be maintained within specification limits (50 ppm max.). Also, the material should be suitable for use as a vapor degreasing agent provided an effective "sump" inhibitor has been added to inhibit break-down as the solvent becomes contaminated.

D. Investigation of Cracking of S-IC Stage Ring Baffles

The metallographic study of S-IC ring baffle cracks, initiated on the discovery of failed units in the S-IC "A" structure, has been resumed as a result of the discovery of cracked baffles in S-IC-T and several

flight stages. The initial studies of the 0.040 inch thick 7079-T6 aluminum parts identified stress corrosion as the crack initiating mechanism. Metallographic and fractographic studies of S-IC-T vehicle baffles are in progress. Metallographic studies to date indicate that the thermal treatments and forming operations applied to the material during baffle fabrication destroys the normal grain directionality associated with sheet material, creating a grain structure that permits the formation of stress corrosion cracks at the surface of the sheet.

## II. Contract Research

During this report period, Saturn-related supporting research activities have continued in the fields of technology with the contractors and under contract numbers listed below.

### A. Polymer Research, Development, and Testing

1. Thiokol Chemical Corporation, NAS8-21197, NAS8-21149
2. University of Florida, NAS8-20247
3. Peninsular ChemResearch, Incorporated, NAS8-5352

### B. Assessment and Evaluation of Blast Hazards

Edwards Air Force Base, Government Order H-61465

### C. Nondestructive Testing Techniques

North American Rockwell, NAS8-20764

## III. S-II Stage

### A. Evaluation of Corrosion Characteristics of 2014-T651 (-063 Material) Aluminum Tank Materials

The tests to determine the susceptibility of 2014-T651 (-021 and -063 material) to stress corrosion cracking in the alternate immersion tester have been terminated after 90 days exposure. Outdoor exposure of both -021 and -063 materials is being continued. Round tensile specimens made from the original -063 material received from Reynolds Aluminum Company and also 2014 plate from Kaiser and Alcoa stressed in the short transverse grain direction to 3, 5, and 10 ksi have been exposed in the alternate immersion tester for 23 days. The results are being reported daily to North American Rockwell (NR). Specimens made from the material of all three companies, Alcoa, Kaiser, and Reynolds are being exposed to local atmosphere stressed in the short transverse grain direction to 25 and 40 ksi. There has been only one failure after 4 days of exposure (a specimen from Reynolds plate No. BG50306-1 loaded to 25 ksi).

In the study of the difference in the general corrosion of the two materials (-063 and -021), tensile specimens of bare and Alodine coated materials were cut from the panels after an exposure to a five percent salt spray. Average values of all groups did not show a greater loss of properties in the -063 materials as a result of the salt spray exposure. Very little difference was noted in most cases; however, in the case of bare specimens, the average elongation loss of the -063 material was much less than the -021 material. On the panels processed through an alkaline etch cleaning cycle, there was slightly more surface attack on the -021 material; however, the depth of attack was about the same on all materials. To summarize the general corrosion and processing characteristics of these two materials, there was essentially no major differences in the two materials. One factor that must not be omitted, is the intergranular attack that occurs in 2014-T6 large grain extruded material (found in the S-IVB program) in the heat affected zone (boundaries) of weld areas when etching with a strong alkaline material for weld defects. This attack interferes in the flaw-detection techniques by indicating a flaw whenever the dye penetrant can be retained in these areas.

B. Investigation of Fracture Toughness

Investigations have continued in the study of the fracture toughness characteristics of aluminum alloys.

1. Compact-crackline-loaded specimens have been machined from the following alloys for evaluation at room temperature, -320°F (-196°C), and -423°F (-253°C): 2014-T651, 2021-T8E31, 5456-H343, and 7007-TE136.

2. On the NR program, equipment has been assembled and tests made which indicate SWE (stress wave emission) at two percent of failure stress.

3. The Boeing Company (TBC) has completed the original test requirements to determine fracture toughness data to assess the J-2 engine start bottle (gaseous hydrogen) proof requirements. Analysis indicates that the bottle in contact with hydrogen at -200°F (-129°C) has a life of 61 cycles and 36 cycles based on parent metal and heat affected zone (HAZ) of the weld respectively. However, on its own initiative, TBC is running a new program at no cost requiring extension of the program to August 5, 1968. The intent is to determine the flaw growth threshold for the titanium in air at -200°F (-129°C) since extremely low threshold values were determined for gaseous nitrogen at -200°F (-129°C) during testing. This condition would represent the external surface condition of the bottle between the titanium and insulation.

C. Investigation of Nondestructive Techniques for Inspection of Composite Materials

1. Evaluation of Spray Foam Insulation

The objective of this work is the development of methods and instrumentation required for the nondestructive evaluation of debonds and

voids in spray foam aluminum composite materials of the type and configuration used on the S-II stage. The particular spray foam insulation being investigated is the NOPCO BX 250A polyurethane foam which has a nominal density of 2 PCF.

An audio frequency "Resonant Foam Coupler" developed to detect lack of bond between foam and metal when access is limited to the foam side of a composite structure works well when used to evaluate laboratory specimens. However, unreliable indications were obtained when pressure was applied to hold the transducer against vertical composite panels. Recently, housing to support the transducer has been designed. This new method of supporting the resonant foam coupler should eliminate or reduce the problem of pressure variations. Additionally, the frequency response of this type of transducer has been increased by reducing the mass of imbedded magnets.

2. Nondestructive Evaluation of Bond Strength

Several nondestructive methods are available for detecting lack of bond between layers of composite materials. However, no entirely satisfactory method has been developed for measuring the strength of adhesive bonds.

A contract, NAS8-20764, was negotiated with North American Rockwell (NR) to develop improved bond strength measuring instrumentation. The equipment will be available to this Center in December. Thus, an in-house program has been initiated to evaluate a Fokker bond tester and the system being developed by NR. Lapshear and honeycomb cored composites will be evaluated with both instruments.

The objectives of this program are to:

a. Determine the capabilities and the limitations of the Fokker bond tester as applied to honeycomb composites.

b. Evaluate bond measuring instrumentation being developed by NR.

c. Compare bond strength indications obtained with both instruments to true bond strength values measured by destructive tests.

A detailed program plan has been prepared and test specimens have been designed. This includes the lapshear and the honeycomb cored types. Determinations are being made of the amount of precuring required to degrade adhesives to specified levels. Subsequent to these determinations, test specimens will be prepared and evaluated.

D. Investigation of Nondestructive Techniques for Inspection of Inert Gas Welds

The objective of this project is the standardization of nondestructive technology for inert gas welds of the Saturn S-II stage propellant tanks. The most effective techniques are to be optimized and their performance is to be established. Aluminum 2014-T6 weldments 0.392 inch thick are now being evaluated. These weldments have been nondestructively evaluated with

radiography and with several ultrasonic techniques. Manual, mechanized A-scan, C-scan, and through transmission C-scan ultrasonic tests have been completed. Information contained in the charts or scanning records has been reduced to numerical data for subsequent comparison with destructive results.

E. Development of Vibration Dampening Material for S-II Stage Hydrogen Line Bellows

Stainless steel liquid hydrogen lines in engine areas, fabricated in a bellows configuration for flexibility, have a tendency to resonate as the fuel passes through, and occasionally this results in line failure. It has been observed that formation of frost on the line dampens the resonance sufficiently that damage does not occur. Several polyurethane formulations, therefore, have been prepared and screened for potential use as resonance dampening coatings on liquid hydrogen lines. The material required should be of low enough viscosity that application to the steel mesh covered bellows-tube may be accomplished through hypodermic needles inserted through the steel mesh. Cure should be possible at room temperature and some flexibility should remain at the temperature of liquid hydrogen.

Formulations were based on Narmco 7343, cured with MOCA, with castor oil, and with mixtures of MOCA and castor oil. Varying quantities of finely ground $SiO_2$ (Cab-O-Sil) were used for improving low temperature flexibility, and acetone was employed as a thinning solvent. Cast disc specimens of each formulation were dipped in liquid nitrogen to test for cracking under thermal shock, and relative elongations at -320°F (-196°C) were obtained from stainless steel lapshear tensile specimens. On the basis of these tests and the requirement for room temperature cure, the formulation selected for further evaluation was: 100 grams 7343; 18 grams castor oil; 6 grams MOCA; 6 grams $SiO_2$; 20 grams acetone.

F. S-II Stage Project Management, Materials

Efforts have continued on the coordination and resolution or problem areas of a materials nature related to the S-II stage. During this report period these efforts have included the following:

1. Investigation of 2014-T651 purchased from Reynolds (material which had special processing at Reynolds) has continued. The results of stress corrosion tests indicate the material is definitely more susceptible than regular 2014-T651 although grain size and mechanical properties are like the regular 2014-T651. The S-II-9 stage is the first constructed with panels of this material and is also the first stage to have primer M-602 on the interior of the liquid hydrogen tank to prevent corrosion. Therefore, assuming the primer M-602 is properly applied, the special material is protected adequately against stress corrosion and is considered safe for hardware use.

2. Investigation of Insulation Problems

a. Failure at Bolting Ring and Cylinder No. 1; S-II-503

During a routine insulation leak check at the John F. Kennedy Space Center (KSC) a debond developed between the tank sidewall

and the pour foam insulation blocks on the S-II-503 stage. There was no prior experience of such failures on S-II-501, 502, or 503 prior to the cryoproof test. S-II-504 experienced insulation failure of both the bolting ring and cylinder No. 1 at KSC during the leak check. Both 503 and 504 had undergone the L006 leak check at Mississippi Test Facility (MTF) after the cryoproof test without similar failure. North American Rockwell/Space Division (NR/SD) explains this by stating that the second cycle of leak test (performed at KSC) is required to cause total failure. NR/SD believes the cryoproof strain (0.004 in/in) in conjunction with the cryogenic strain (0.027 in/in) cause the debond of the primer M-602/Narmco 7343 insulation bonding system from the tank sidewall. While the explanation is plausible, there is no simple way to prove it without tests on an actual S-II stage because of the unique configuration of the bolting ring and cylinder No. 1. S-II-505 has experienced only one cryogenic loading (cryoproof test at MTF) and could be used to establish a valuable data point if evaluated prior to static firing. However, because of schedule problems, this was not permissible.

The proposed fix for S-II-503 is to bond in new pour foam blocks over the complete cylinder No. 1 using primer M (not primer M-602 since it must be heat cured) and Narmco 7343 re-enforced with a scrim cloth. Experiments with this system on the McDonnell Douglas Company (MDC) test tank (Thor tank) at Sacramento indicated the system will withstand a 0.054 in/in cryogenic strain without debonding or cracking. Prior to using this fix on 503 it was proposed to experiment with the fix on 505 by replacing 3 or 4 of the blocks with this system, static fire, and evaluate after firing. Otherwise, the first stage experience of this system will come with the countdown demonstration test (CDDT) of S-II-503. Again, the schedule problem precluded this test.

b. Investigation of Corrosion Under Feedline Elbow Insulation

During a repair of the feedline elbow purge system of S-II-504 at KSC corrosion was noted on the tank sidewall. Further removal of the insulation revealed that most of the insulation (pour foam) had debonded and the entire sidewall had general pitting corrosion. The corrosion has been removed, the typical depth 3 to 5 mils with the deepest being 15 mils in a 125-mil thickness.

NR/SD has stated that the insulation was not installed per the engineering drawing and that they do not know the reason why. Specified applications required primer M and pour foam while the actual application was primer M - Narmco 7343 and pour foam. Several months ago (during similar problems with S-II-501 and 502) NR/SD was advised to eliminate the use of the Narmco 7343 to preclude further such problems. It has since been determined that the primer M - Narmco 7343 - pour foam system has been used until this time in manufacturing and field repair. There is no explanation for this. In all probability, all current stages will require rework in the feedline elbow area.

Poor workmanship has been evidenced in the application of the 3 lb/cu ft density pour foam since that which was removed from S-II-504 measured from 6.4 to 36.4 lbs/cu ft density. No fix has been proposed.

S-II-503 was reworked at KSC prior to the cryoproof at MTF. Recent investigation of the reworked area does not show evidence of new corrosion at this time.

c. Recirculation Pump Electrical Connectors

During the removal of insulation on the S-II-504 feedline elbow circuit, it was disclosed that the recirculation pump electrical connectors not only had corrosion problems but because of improper manufacturing practice, pour foam had penetrated to pump receptacles preventing proper contact.

Engineering specified 5 layers of tape around the receptacles but only one layer has been the manufacturing practice. Again there is no explanation for this.

Thus far it has been determined that S-II-503, 504, and 505 require rework, and in some instances replacement of recirculation pumps.

3. S-II "B" Structure Failure

The "B" structure failure has been isolated to a structural splice joint of the forward skirt cylinder quarter panels (stringer #50). This stringer is a composite "I"-beam section made of two back-to-back channels bolted together. A representative of this division reports that one bolted web of the channel section of stringer 50 was cracked prior to failure as evidenced by RTV material (sealant) in the crack. This occurred apparently during joining of quarter panels at NR, Seal Beach. The primary structural failure was in the flange of the composite "I"-beam section riveted to the quarter panel skin. It has not been determined definitely that these assembly cracks were the primary cause of failure.

The assembly cracks are described as originating at the interface where two channels are joined by bolts and RTV to form an "I"-beam. In the web of one channel the major crack was 35 inches long at the joint interface, extending through the 1/4 inch thickness, measuring 15 inches on the opposite side. Several small cracks, approximately 1 inch long, parallel the 35-inch crack but do not extend through the material thickness.

IV. S-IVB Stage

A. Investigation of the Effects of Water on Korotherm 793-009 Insulation

Efforts have continued in the study of the effects of water on the frictional characteristics of Korotherm low-temperature ablative coating. As reported earlier, water leaches out some of the sublining compounds of the Korotherm, resulting in degradation of its insulating qualities. Tests were made to determine whether water had any appreciable effect on the structural integrity of the Korotherm. For these tests, specimens of Korotherm applied

to aluminum panels were immersed in water until blisters, filled with water, formed in the Korotherm coating. The specimens were air dried until the blisters receded followed by a heat cure at 95°F (35°C) for 5 days. These specimens were then exposed to a thermal-vacuum environment simulating the conditions the insulation will experience during S-IVB ascent. There was no apparent change in the Korotherm until it reached a temperature of 350°F (188°C) (the approximate temperature at which the Korotherm starts subliming). At this temperature, blisters (3/8-inch diameter and smaller) formed in the Korotherm coating. The water-filled blisters, which receded during drying, did not reform during the thermal-vacuum test, indicating that Korotherm which has been exposed to water and then dried is a suitable base for the application of other insulative coatings.

Additional tests were made to study the performance of DC 92-009 vapor barrier coating when applied over the Korotherm insulation. Specimens of Korotherm were coated with 6, 14, 20, and 50-mil thick coats of DC 92-009 and exposed to a thermal-vacuum environment simulating conditions the Korotherm will experience during S-IVB ascent. The results show that the Korotherm starts outgassing at temperatures between 150°F and 250°F (66°C and 121°C). (The temperature was controlled and measured on the outer surface of the DC 92-009.) The samples having the thinner coats (6-mil and 14-mil) started outgassing at approximately 150°F (66°C), forming blisters underneath the DC 92-009 which burst immediately after forming. The samples coated with the 20-mil and 50-mil thicknesses of DC 92-009 started outgassing at 200°F and 250°F, (93°C and 121°C) respectively, forming blisters underneath the DC 92-009 coating; however, the blisters did not burst immediately, but increased in size until the DC 92-009 coating completely separated from the Korotherm before bursting. Additional tests will be made on samples with a white epoxy paint applied between the Korotherm and DC 92-009.

B. Investigation of Failure of S-IVB Servoactuator

An S-IVB stage servoactuator developed a crack in the Ti-6Al-4V tailstock during recent tests at the Astrionics Laboratory. The stainless steel cam had also failed. The actuator had been in service on the S-IVB engine simulator for an extended period of time. Metallurgical analysis of the failure is in progress. Results of these investigations will be reported when they are complete.

C. Investigation of Failure of an S-IVB Attitude Control Motor

Very short duration firings (order of 65 msec) at ambient conditions with a delay between firings of several days has resulted in the successive reduction of combustion chamber pressure in the S-IVB attitude control motors.

On July 10-11, 1968, a 150-pound thrust S-IVB attitude control motor was disassembled in an effort to determine the cause of the decrease in combustion chamber pressure. The disassembly took place in the following sequence with the results as noted.

It was observed that liquid was in the tubing connecting the valves to the oxidizer injectors. Also, some liquid was in the fuel lines. The liquid in the oxidizer lines contained some $N_2O_4$ but was mostly nitric and nitrous acid (the reaction products of $N_2O_4$ with water). The liquid in the fuel line was analyzed by an infrared spectrophotometer and shown to be monomethylhydrazine. The liquid in the oxidizer lines was colored light green. An emission spectrographic analysis indicated a heavy concentration of nickel, iron, and chromium with traces of gold and copper. Inspection of the solder and tubing interface in the flange showed some pitting and roughing of the surfaces (as would be expected to occur in a nitric and nitrous acid environment).

A section of one of the oxidizer tubes was removed and opened. Inspection of this section revealed no scale formation or other particle formation which would restrict fluid flow.

The oxidizer tubes which were soldered in the motor head were slowly machined away and periodic inspections made to determine whether particles or scale was restricting fluid flow. The inspections revealed no significant blockage of the injectors or tubing.

Valves were disassembled. No particulate contamination was observed.

No definite conclusions as to the positive cause of the chamber pressure decay were drawn from the motor inspection. Possible mass flow rate tests of oxidizers and fuel through the valving and injector plate have been suggested and discussed with representatives of the Propulsion Division.

## V. Instrument Unit

### Investigation of Corrosion on Tubing From Instrument Unit 501

A section of 6061 aluminum tubing removed from the environmental control unit of Instrument Unit 501 was received for metallographic examination of a pitting condition that existed on the inner surface. The study revealed intergranular attack at pit locations to depths of 0.009 inch.

## VI. F-1 Engine

### Investigation of Cracks in Hydraulic Lines at F-1 Engine Test Stand

Cracks were recently discovered in the main LOX and fuel valve hydraulic lines on the Test Laboratory's F-1 bobtail engine stand. The lines are modified flight configurations units. A metallurgical analysis of the failures is in progress.

## VII. Saturn IB Workshop

### A. Study of the Flammability of Materials

Investigations have continued in the determination of the ease of ignition and flammability of various materials proposed or considered for use in the Saturn IB Workshop.

During this period, a number of materials were evaluated for flammability by the procedures outlined in MSFC-SPEC-101 (Proposed), "Flammability Requirements and Test Procedures for Materials in Gaseous Oxygen Environments." The samples included various elastomers, adhesives, sheet materials, and plastics. Samples of three new materials from Raybestos-Manhattan based on the Minnesota Mining and Manufacturing Company Fluorel compound L-2231 have been evaluated for flammability. The compounds included L-3492 conformal coating, L-3203 adhesive, and L-3550 sealant. All of the above materials met the requirements of Type I materials of MSFC-SPEC-101. Type I materials shall be non-combustible in the vertical position when exposed to an energized ignition source placed at the bottom of the sample for a minimum of 10 minutes.

Work has continued on setting up the test articles for the new evaluation of three foot diameter specimens using the induced draft blower system rather than the forced draft blower system used on previous tests. Test Laboratory has experienced some difficulty in obtaining consistent flow velocities with the test equipment. However, most of the problems have been resolved and testing and evaluation should resume within the next reporting period.

### B. Investigation of Thermal Control Coatings for the Saturn IB Workshop

During this report period emphasis has been directed toward formulation and application techniques of the HXW coating described in the last month's report. Several formulations of the same constituents (HX-610, "N" sodium silicate, glass bubbles, and zinc oxide) have been evaluated. Coatings with variations of pigment volume concentration (PVC) from 0.35 to 0.51 have been sprayed and the optical and physical properties of each evaluated. After consideration of reflection, hardness, water solubility, and surface texture, one formulation has been chosen. Tests have been run on coatings of this formulation to determine the minimum thickness necessary to yield optimum absorption. Results show that a coating thickness of about six mils adheres well and has an absorptance of 0.20. Thicker coatings have better absorptance but do not adhere as well. It may be possible to build a multilayer coating and obtain better absorption. Work is continuing in this direction. Tests were also run to determine a minimum curing time and temperature. Results show that after air drying at room temperature, curing at 180°F (82°C) for two hours is sufficient for the six-mil coating. This curing cycle has eliminated the hot water solubility problem. In addition, the pigment separation problem has been resolved by using a pressure feed spray rather than an aspiration feed spray.

As reported earlier, Narmco 7343/7139, with and without Z-6040 additive, is being evaluated as an adhesive for bonding goldized Kapton to Saturn IB Workshop surfaces requiring emissivity values less than 0.05. The following formulation meets the Workshop vacuum compatibility requirements when cured at room temperature for 24 hours followed by a heat cure at 160°F (71°C) for 48 hours: Narmco 7343 - 100 grams; Narmco 7139 - 11.5 grams. The same formulation containing 1 gram of Z-6040 additive and cured in the same manner does not meet the Workshop vacuum compatibility requirements. Additional samples of the formulation containing the Z-6040 additive will be evaluated. These samples will be cured by extending the heat cure at 160°F (71°C) to 8 days prior to vacuum compatibility testing.

C. Investigation of Saturn IB Workshop Fan

Environmental evaluations of Saturn IB Workshop thermal control fans are being made with particular emphasis on life tests of the fan bearings. Several additional types of fans have been ordered for evaluation as a backup to the present AiResearch fan.

Inspection of the failed bearings from the Workshop fan indicated that the failure was a result of poor lubrication. It appears that the selection of a metal crown type retainer and a silicone grease was the probable cause of the bearing failure. The failed bearings were replaced with bearings having sacrificial retainers and again lubricated with DC 33 grease. The repaired fan has now operated for 200 hours in a 5 psi oxygen environment in the high speed mode. Bearing noise is low and the fan efficiency is high. This test will continue for 1,250 hours with an intermediate vacuum soak after which the bearings will be pulled for inspection.

D. Investigation of the Potential Effects Attitude Control Engine Exhaust on Saturn IB Workshop/Cluster Surfaces

A careful mapping has been made of plume geometries, Mach numbers, temperatures, and heat fluxes of exhausts of attitude control engines on the Saturn IB Workshop/Cluster arrangement. In addition, consideration was given to the possible chemical species residing in these plumes during long duration and pulse firings. This study included the Yaw Attitude Control (YAC) engine of the Workshop Attitude Control System and the Lunar Module/Apollo Telescope Mount (LM/ATM) and the Command Service Module (CSM) attitude control rockets. A general analysis was done to (1) delineate those phenomena that could be expected and factors controlling them, (2) a detailed analysis of the phenomena of evaporation, cooling, and freezing, and (3) the effect of unreacted or partially reacted chemical species due to minor leaks. In addition, consideration was given to the need for possible testing if questionable areas were uncovered.

The exposure of liquids, vapors, or gases to vacuum involves a great variety of phenomena, most of which result directly or indirectly from the suddenly imposed supersaturation. Volatile liquids exposed either in bulk or by leakage usually boil, and the growth and bursting of bubbles breaks the liquid up into a cloud of vapor or droplets. Surface forces and the turbulence and other disturbances created by the flow also contribute significantly to the breakup. Bulk quantities of even nonvolatile liquids also usually boil upon exposure; however, jets formed by the leakage, do not boil, but breakup occurs, a result of the action of surface forces and turbulence. The initial velocity resulting from the breakup process, together with any additional velocity acquired by expansion, disperses the droplet-vapor cloud in all directions at supersonic velocities into the vacuum. Simultaneous breakup, evaporation, and dispersion results in freezing of any vapor usually within a distance of 10 to 40 inches from the orifice.

1. "Y" Attitude Control System (YAC) of Workshop Attitude Control System

Based upon the geometry of the system, it has been established that the plume will not impinge on the Workshop solar array until after the Mach 18 exhaust regime which occurs at a distance in excess of 200 inches along a center line from the rocket chamber exit. At this point, the exhaust gases have a velocity in excess of 11,800 ft/sec and the gas temperature is $\leq$81°K. The impact force was found to be $<1.5 \times 10^{-4}$ lb/ft$^2$. Based upon the chemical species within this exhaust plume, all liquidus materials would reach their triple point at <40 inches away from the engine exits. In addition, the plume should impinge on the Workshop aft section at around the Mach 17 limit contour. Gas temperature is expected to be <89°K. The gas velocity would be >11,800 ft/sec with an impact force of $1.85 \times 10^{-4}$ lb/ft$^2$. Based upon these data, no deleterious effect is expected from the YAC engine plumes to either the Workshop solar arrays or to external surfaces of the Workshop.

2. Multiple Docking Adapter and Lunar Module/Apollo Telescope Mount

During the LM/ATM docking maneuver of the Lunar Module/Apollo Telescope Mount (LM/ATM) the +X engine exhaust of the LM is expected to impinge on the Multiple Docking Adapter (MDA). However, based upon the plume geometry and the distance involved, this is not expected to be less than the Mach 11 contour. The impact force constant will be 0.0143 lb/ft$^2$ at a temperature around 203°K. Therefore, no damage or degradation to the MDA surfaces are expected. Since the ATM solar array is in the retracted position no degradation can occur to these surfaces from the rocket plume. Based on present information, these +X LM engines will not be utilized after the docking maneuvers. Therefore, the ATM solar arrays will not be in jeopardy.

3. Command Service Module

The +Y engines on the Command Service Module (CSM) expected to impinge on the ATM solar arrays during attitude control maneuvers. Since

these engines are >310 inches away from these arrays, problems are not expected; however, computer data are not presently available to verify this assumption. It is expected that this program will be completed during the next reporting period.

## VIII. Multiple Docking Adapter (MDA)

### Investigation of Resistance to Micrometeoroid Penetration of the Multiple Docking Adapter (MDA)

Micrometeoroid impact simulation tests on the MDA bumper and high performance (HP) insulation configuration have been continued. As shown last month the proposed bumper configuration is capable of defeating a projectile with mass and velocity near the penetration threshold as calculated by the Structures Division. The projectile used last month was a 0.090-gram sphere of 7075-T6 aluminum traveling at 6.58 km/sec (21,600 ft/sec). The object of the program now is to determine what the actual penetration threshold is so that a survival probability can be calculated. To accomplish this purpose, both the projectile mass and the projectile velocity were increased to 0.118 gram and 7.05 km/sec (23,100 ft/sec), respectively. One MDA bumper configuration target has been tested with a projectile with these increased parameters. Again almost negligible damage was done to the 0.125 inch thick aluminum wall, although a slight bulge was visible. The debris generated by the bumper impact in this test did punch a larger hole in the foam-aluminized Mylar layered insulation. Procedures are presently being developed to raise the projectile mass and velocity even further.

Testing has begun on MDA electrical cables (routed external to the MDA). Two bundles of 2 cables each 1.5 inches apart enclosed by the standard MDA bumper were tested at a projectile mass of 118 milligrams and 20,600 ft/sec velocity. No conductors were severed, but insulation was stripped off many of the individual wires. Testing will continue on both these configurations at a higher velocity.

## IX. Apollo Telescope Mount (ATM)

### A. Investigation of Contamination and Contamination Sources

Evaluation of potential materials for use on the Apollo Telescope Mount (ATM) is continuing. All materials are tested in accordance with the Materials Property Criteria established in the Materials Management Plan for ATM contamination. To be acceptable, a material must have a maximum rate of weight loss during temperature cycling from 25°C (77°F) to 100°C (212°F) which does not exceed 0.2 percent/$cm^2$/hr.

1. Materials Tests

Kodak SO 392 2.5-mil Estar film, Monobond M-2 adhesive, Narmco adhesive I-A (100 grams Narmco 7340, 11.6 grams 7139) and Alstan 70 low emissivity gold coating were tested and found acceptable for use on ATM. PS-267 adhesive, Windham epoxy adhesive #37-128/600, Midland aluminum paint 3X258 and Narmco adhesive II-A (100 grams Narmco 7340, 11.5 grams Narmco 7139 and 1 gram Dow Z-6040), and Soldereze magnet wire were tested and found unacceptable for use on ATM. Technit 45-09802 gasket material, previously rated unacceptable may now be rated acceptable, but only after vacuum bakeout at 100°C for 48 hours.

2. Components Tests

An ATM memory module has been exposed to a thermal/vacuum environment. The memory module initially outgassed heavily, with peaks to 241 AMU, but after 24 hours in vacuum the unit began to attain an acceptable outgassing rate. This unit will be rated acceptable after thermal/vacuum bakeout for 48 hours at 85°C.

B. Investigation of Lubricant and Lubricity Requirements for ATM

1. To protect moving parts of the Apollo Telescope Mount, lubricants will be required which will not break down or outgas in the environment of outer space.

Because of the poor condition of the dry lubricated gears after 56 days operation in the Bendix control moment gyro gimbal test system additional tests will be made on a system equipped with Nitraloy gears coated with MLF-2. It is believed that the selection of 420 steel for the present gears contributed to the lubricant failure. These tests will continue as soon as the new test system is received from Bendix.

2. Journal bearings identified as DU type have been selected for use by the Perkin-Elmer Company for use at several locations on the ATM pitch and yaw, and roll systems. These bearings are being evaluated under vacuum and earth ambient conditions as well as at high and low temperature extremes.

Vacuum, air, and high temperature testing have been completed. Low temperature tests will be started in a few days. In general the wear life of these bearings appears to be satisfactory except for an unexplained failure in one 1-1/2 diameter bearing. It appears, however, that the bearing friction is generally higher than shown in the manufacturer's literature particularly in the small diameter bearings.

3. Because of extremely long life requirements on the ATM and other orbital spacecraft it is questionable if dry film lubricated gears will successfully meet these requirements. A new gear design consisting of a sloped sandwich of alternate layers of steel and Teflon has been designed, and manufactured. These gears will be evaluated for extreme life conditions in a simulated space environment.

A set of the sandwich type gears of 300 series stainless steel and Teflon have operated successfully at light loads in vacuum for over 1,000 hours with little wear. Additional gears of 4340 steel and Salox M are being manufactured for tests at higher loads. A patent disclosure has been sent to the local Center Patent Council.

## X. Nuclear Vehicle Technology

In-house and contractual studies are being pursued to develop the materials technology required to support a potential nuclear-propelled vehicle program. Specifically, the areas of cryogenic insulation, valve seals, transducer materials, gimbal and bearing lubricants, and induced neutron activation are being investigated.

### A. Propellant Heating Experiment

Modification 5 to contract NAS8-18024 with the General Dynamics Corporation (GD/FW) provides for an experimental program to study the nuclear and thermodynamic effects caused by the deposition of nuclear energy in liquid hydrogen. The data obtained from this study is needed for the analysis of the credibility of results predicted by existing analytical techniques and for the design of future stage propellant systems.

A memorandum was written to the Test Laboratory (R-TEST) requesting the use of a transonics digital data acquisition system (DAS) for the propellant heating experiment. Currently, the inability to locate a suitable DAS is the major problem confronting the program. If the DAS in R-TEST cannot be made available, contract funds will have to be allocated for the purchase of this equipment which will necessitate a reduction in the program level of effort. The drawings and specifications for the double wall tank to be built by Cayenco have been completed by GD/FW and are being transmitted to this Center for review and approval. The tank T.V. surveillance system has been designed and is being fabricated. The present schedule calls for the test program to commence in February 1969.

### B. Rift Tank Tests

Currently, tests are scheduled to be made under contract NAS8-18024 with GD/FW to evaluate various types of transducer, seal, and insulation materials in a radiation, liquid hydrogen, and acoustic environment. The tests will be made using the 108-inch diameter liquid hydrogen ($LH_2$) Rift tank insulated with the test insulation. Valves and transducers containing the test materials will be installed on the tank for testing.

Three sets of four types of candidate valve seal materials were received from Whittaker Corporation, irradiated to exposures of $1 \times 10^7$R, $5 \times 10^7$R and $1 \times 10^8$R; and returned to Whittaker Corporation for testing.

The spraying and machining operations associated with the application of the Upjohn CPR-385-2 polyurethane foam on the Rift tank have been completed and the protective covering of resin-impregnated fiberglass is now being applied. The current schedule calls for the shipment of the tank to GD/FW on

August 1, 1968. Arrangements have been made for shipment prior to this time of the valve shrouds and other smaller hardware items.

C. Activation Analysis

The computation of neutron activation of proposed Nuclear Rocket Vehicle materials is necessary for the establishment of stage operation criteria. Because of the complicated materials and difficult geometries comprising typical stage hardware, sophisticated computer programs must be used to calculate anticipated activation prediction code (NAP) developed for this Center by IIT under contract NAS8-11160. Currently, efforts are directed toward the implementation of the NAP computer program at this Center.

The input data for the Al-2219 run has been misplaced in the Computation Laboratory; consequently, a new set is being prepared.

## ADVANCED RESEARCH AND TECHNOLOGY

I. Contract Research

Supporting research activities have continued in the areas of technology and with the contractors as specified as follows:

A. Polymer Development and Characterization

1. Southern Research Institute, NAS8-20190
2. National Bureau of Standards, Government Order H-92120

B. Adhesive Development

1. Narmco Research and Development, NAS8-11068
2. Monsanto Research Corporation, NAS8-20402

C. Thermal Control Coatings

The Boeing Company, NAS8-21195

D. Physical and Mechanical Metallurgy

McDonnell Douglas Corporation, NAS8-21470

E. Composite Material Development and Testing

1. Solar, Division of International Harvester, Inc., NAS8-21215
2. McDonnell Douglas Corporation, NAS8-21083
3. Babcock and Wilcox Company, NAS8-21186

F. Lubricants and Lubricity

1. Midwest Research Institute, NAS8-21165
2. The Boeing Company, NAS8-21121

G. Corrosion in Aluminum and Steel

1. Aluminum Company of America, NAS8-20396, NAS8-21487
2. Tyco Laboratories, NAS8-20297
3. Hercules, Inc., NAS8-21207

H. Explosion Hazards and Sensitivity of Fuels

Stanford Research Institute, NAS8-21316

I. Synergistic Effects of Nuclear Radiation, Vacuum, and Temperature on Materials

1. General Dynamics Corporation, NAS8-18024
2. Hughes Aircraft Company, NAS8-21087
3. IIT Research Institute, NAS8-21031

J. Investigation of Sealant Materials

Monsanto Research Corporation, NAS8-21399, NAS8-21401
Battelle Memorial Institute, NAS8-21398

II. General - In-House

A. Development of High Temperature Resistant Polymers

Continued emphasis in this area has been placed on development of effective crosslinking systems for the aryloxysilanes, silphenylenesiloxanes, and polymers of related structure. The uncured vinyl-containing aryloxysilane polymer described in previous reports has been characterized by significant hydrolytic instability. Lapshear adhesive specimens are being prepared from the cured polymer for high humidity aging tests. Attempts will be made, as time permits, to formulate polymer variants which afford steric shielding of the Si-O bond through bulky groups attached to the Si atom. Another factor which may enhance the rate of hydrolysis is presence of trace quantities of the polymerization by-product, dimethylamine. The amine is extremely difficult to remove completely from the aryloxysilane polymer. It was first thought that evaporation of toluene solutions of the polymer to dryness would remove residual amine, but trace quantities were observed following such operations. No further effort will be expended on the residual amine problem until the extent of amine participation in the hydrolysis reaction is determined.

The trifunctional silicon hydride curing agents, 1,3,5-tris-(dimethylsiloxy)benzene, and 1,3,5-tris(dimethylsilyl)benzene, have not been successfully prepared by the reaction methods attempted to date. No further effort on these compounds is anticipated unless more attractive synthetic approaches are devised.

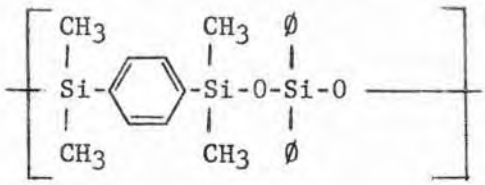
B. Development of Fluorinated Adhesives

Poly(perfluoro-oxidiazoles) are prepared by reaction between a perfluoro-dicarboxylic acid diacylchloride and an equimolar quantity of the corresponding dihydrazide to yield a polyhydrazide which may be thermally dehydrated to the desired polyoxadiazole. The dihydrazide of perfluoroglutaric acid has been prepared by conversion of perfluoro-glutaric acid to the diethyl ester and subsequent treatment of the latter with hydrazine. The dihydrazide will be reacted with perfluoroglutaryl chloride to yield the highly fluorinated polyoxidiazole.

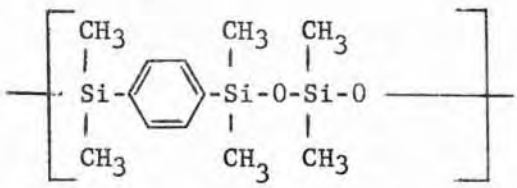
C. Development of Sealant Materials

Efforts have continued during this reporting period to develop new and modified polymers for use as high temperature, fuel-resistant sealants for aircraft fuel tanks.

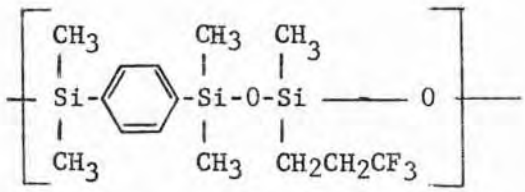
A study of the fuel resistance of various candidate sealants is currently being initiated. Three silphenylenesiloxane polymers,



(I)



(II)



(III)

have been appropriately cured and fabricated into micro-tensile specimens for inclusion in the study. Polymers (I) and (II) are to provide reference fuel resistance data for nonfluorinated systems. Comparative data from polymer (III) should indicate the amount of fuel resistance conferred by its

pendant fluorinated group. A soxhlet extraction apparatus has been modified to act as a fuel exposure chamber. Tests are now in progress to determine if the desired 500°F (260°C) exposure temperature can be approximated in this apparatus. The initial fuel exposure studies are being conducted with RP-1 fuel, which contains 5 percent aromatics and boils in the range of 360-525°F (182-274°C).

Additional synthesis studies have been carried out to prepare various fluorinated polymer intermediates. The preparation of bis(dimethylamino)-bis(pentafluorophenyl)silane has been attempted as an intermediate to more highly fluorinated silphenylene polymers. The first step of this synthesis involved preparation of dichlorodiethoxysilane, which was accomplished by treatment of tetrachlorosilane with anhydrous ethanol at 14°F (-10°C) using carefully controlled reactant stoichiometry. The product, a colorless liquid boiling at 277-279°F (136-137°C), was recovered only after a tedious fractionation using a high efficiency column with a high reflux ratio. One mole-equivalent of this product was condensed with two mole-equivalents of pentafluorophenylmagnesium bromide at 77°F (25°C) over a period of 24 hours. A flocculent white precipitate indicative of the condensation by-product was formed during addition of the chlorosilane. The reaction product, presumed to be bis(pentafluorophenyl)diethoxysilane, is being isolated prior to regeneration of the dichloride. The dichloride, in turn, is to be exhaustively dimethylaminated to form the required polymerization intermediate.

The study of fluorinated aryloxysilane polymers has continued with alternate attempts to prepare the intermediate, 2,3,5,6,2',3',5',6'-octafluoro-4,4'-dihydroxybiphenyl. Conversion of the diamine to the diphenol through the diazonium salt intermediate was not successful. An apparently more successful approach has involved hydrolysis of octafluorobiphenyl with strong, aqueous sodium hydroxide followed by regeneration of the phenolic groups with acid. A white solid, assumed to be the desired diphenol, has been isolated during the acidification step. Purification and characterization procedures are currently in progress.

## D. Development and Evaluation of Metallic Composites

Investigations are continuing in the development of light weight high strength metallic composites by means of various forming and bonding techniques.

### 1. Vacuum Infiltration Studies

An evaluation has been made of boron-magnesium composite specimens prepared by vacuum-infiltration of boron fibers with molten magnesium. These composite specimens had an ultimate strength of 101,000 psi and a modulus of $36.12 \times 10^6$ psi. The strength to density ratio of specimens having a boron fiber volume content of 46 percent was $1.37 \times 10^6$ inch.

2. Explosive Bonded Materials

Studies have continued in the experimental determination of explosive bonding parameters required for joining various dissimilar metals. Seven additional samples of high purity metals were successfully bonded by explosive techniques during this report period.

3. Investigation of Diffusion Bonding Techniques

Studies have continued in the development and evaluation of wire and whisker reinforced aluminum prepared by diffusion bonding. Several specimens were prepared consisting of NS 355 wire in aluminum and wire and whiskers of silicon carbide on aluminum. These composite specimens are being studied to wire volume content and micro metallographic characterizations are being made.

E. Investigation of Stress Corrosion Characteristics of Various Alloys

Because of the severe corrosion of the standard 3-1/2 percent salt solution on the 2000 series alloys, studies are being made to determine the feasibility of using synthetic sea water environment for testing aluminum alloys. Tests have been planned for 2014, 2017, 2024, 7001, 7075, and 7039 in 1/8 and 1/4 inch diameter specimens and will be placed in test when fixtures become available. In connection with the study of the S-II North American Rockwell tank material, tests of this material are also being conducted in synthetic sea water.

Initial tests have been terminated in the evaluation of the stress corrosion susceptibility of Almar 362, PH15-7Mo, 17-4PH, and PH14-8Mo (air and vacuum melt) and the final properties are being evaluated. Additional specimens of PH15-7Mo and 17-7PH steels at lower stress levels and initial stress corrosion specimens of PH13-8Mo steels have been exposed for 167 and 101 days respectively, in the alternate immersion tester.

Round tensile specimens made from 1/4-inch diameter music wire spring material were stressed in the longitudinal direction to 70 percent of its yield strength and exposed in the alternate immersion tester. The test was terminated after 4-1/2 months because of excessive surface corrosion with no failures having occurred. Similar tests in the humidity cabinet, outside atmosphere, and semi-controlled atmosphere are continuing. There have been no failures in any of these environments after 230 days of exposure.

F. Investigation of Stress Corrosion Induced Property Changes in Metals

Investigations have continued in the attempt to develop nondestructive methods of detecting incipient stress corrosion failure in launch and space vehicle hardware.

Previous in-house studies have clearly shown trends in material degradation caused by stress corrosion. However, the scatter of data points has been greater than desired. These same experiments have indicated that variation in specimen loading is a major contributing factor to the scattering of data points. Efforts are being made to solve this problem. A mechanical device for measuring specimen loading has been developed and is being calibrated with strain gages. Thus, specimen loading will be controlled with much better accuracy. Prior to loading, specimen uniformity will be checked with ultrasonic surface waves. These two additions to our experimental procedure are expected to yield better data.

G. Evaluation of Ultrasonic Stress Measurement Methods

Instrumentation for nondestructively measuring stress has been developed for this Center by a contractor. An in-house program designed to verify the contractor's claims for this equipment and to improve the system is being accomplished. Numerous electronic, acoustic, and mechanical factors which could affect the accuracy and the practicality of the system are being investigated.

Attempts to make frequency-null system measurements on a Ti-6Al-4V titanium alloy specimen were unsuccessful due to nonrepeatability and lack of correlation. Recent time of flight measurements versus stress with knife edge transducers and laboratory apparatus have been made. Fair correlation was obtained between the time of flight in nanoseconds and the stress as measured by strain gages.

Experimental stress measurements have been made on a 6061 anodized aluminum bar using the frequency null system. No correlating effect between stress and the ultrasonic frequency factor was observed. To check the validity of these results, measurements on the bare 6061 bar were repeated. Good results were obtained a second time on the bare aluminum bar. Apparently, the anodize destroys the ability to make ultrasonic stress measurements.

H. Development and Evaluation of Materials for Electrical Contacts in Vacuum

Electrical contacts in vacuum concerns any device for transferring electrical energy through moving surfaces, such as brushes, slip rings, and make-break switches. Standard brush-commutator type machines suffer a severe degradation of performance at high altitudes, principally due to rapid wear of the graphitic carbon brushes. This results from failure of the normal process of lubrication of the contact surfaces. Therefore, this program was initiated to develop electrical brushes for use in a space environment.

The Boeing 046-45 brushes ($MoS_2$-Ta-Mo) are being characterized as functions of current density, surface speed, and wear rate through tests on 7 ft-lb high temperature Inland torque motors. The test system consists of two torque motors each possessing four brushes that are loaded to 5 psi. These are connected through a 5:1 gear system, allowing four brushes to be tested at 5 times the speed of the other four brushes. The test time has been extended from 24 hours to 96 hours so that a significant amount of brush wear will accumulate, and thereby reduce errors in wear measurements.

I. Development of Low Density Ceramic Foams

Investigations have continued in the study of the effects of compositional variations and processing techniques for ceramic foam materials.

Results of further tests on the load penetration properties of submerged sodium silicate foams indicated that the water resistance of microwave-oven-foamed material (microwave foam) was inferior to conventional-oven-foamed material (oven foam) of the same batch composition. In addition, the debris from the water break-up of the microwave foam contained large quantities of recognizable bundles of Refrasil fiber whereas Refrasil fiber has been found in the oven foams only with great difficulty even under the microscope.

The substantial difference in failure time and mode suggested a reaction between the sodium silicate and Refrasil was occurring during the conventional oven foaming process. To test this assumption, a standard sodium silicate-Refrasil mixture was slowly boiled on a sand bath. The Refrasil was completely digested in less than six hours. This digested sample was then foamed in the conventional oven by the standard process. Moisture resistance tests and visual appearance indicate foam from the digested sample is equivalent to foam from sodium silicate-Refrasil mixtures. This result implies that the Refrasil fiber does not reinforce the foam, as had been thought, and that the Refrasil serves as a source of silica to change the $Na_2O : SiO_2$ ratio of the mixture. The differences in performance of the microwave foam and oven foam can be explained adequately: the microwave foam consists of a matrix of sodium silicate, with an $Na_2O$: $SiO_2$ ratio of 1:2.00, containing dispersed Refrasil fiber phase; the oven foam consists (essentially) of sodium silicate with a 1:2.57: : $Na_2O$: $SiO_2$ ratio, with a very minor Refrasil fiber phase.

Since there are cheaper sources of silica than Refrasil fiber, mixtures of differing sodium silicates and of sodium silicate and Ludox colloidal silica, all mixtures having the 1:2.57::$Na_2O$:$SiO_2$ ratio, were then foamed in the conventional oven. There are some differences in the pore structure of the foams produced but the foams are remarkably similar considering the variation in starting materials. The most important implications are that the $Na_2O$:$SiO_2$ ratio controls the foaming action and that this ratio can be suitably obtained by mixtures of two liquid sodium

silicates differing in alkali/silica ratio. This development frees the conventional oven foaming process from the compositional limitation imposed by the maximum amount of Refrasil which can be uniformly dispersed in the sodium silicate.

A limited investigation of the further potential of conventional oven foaming has been initiated. The initial trials have been directed toward determining the optimum foaming temperature of the 1:2.57::$Na_2O$:$SiO_2$ composition. Increasing the foaming temperature above the standard 190°C (375°F) results in a finer and, apparently, more uniform structure; however, at 315°C (600°F) a denser layer has appeared on the bottom surface of the foam. An attempt will be made to determine if programming the foaming temperature influences the formation of the dense layer. After an optimum processing method has been determined approximately, the effect of compositional changes will be studied.

The microwave oven will produce foams from compositions believed not to foam adequately in conventional oven processing and these compositions, principally those with $Na_2O$:$SiO_2$ ratios of 1:3.00 or higher, are being stressed now in the microwave oven experimental work. The expected improvement in water resistance with higher silica content has been verified in submerged, load-resistance tests. Some problems with structure remain the usual closed mold structure consists of large voids distributed in a matrix of uniformly fine bubbles. The effect of fibrous fillers of varying diameter and length is being determined at present. The effect of increasing the silica content in the composition will be determined when the proper materials are received.

J. Developmental Welding

Activity has continued in the evaluation of the weldability of aluminum alloys X2021 and X7007. Tensile properties have been determined for 1/2-inch thick weldments of both balloys. The mechanical properties were determined at ambient and cryogenic temperatures with tensile specimens notched at the weld centerline and notched at the fusion line. Preliminary results indicate the alloy X2021 weldments are relatively immune to notch sensitivity; however, the alloy X7007 weldments are characterized by a pronounced tendency toward notch sensitivity at cryogenic temperatures.

Welding operations have continued on the weldability study of aluminum alloy 7039. Flat position weldments in one-inch thick 7039 (T61 and T64) have been made with 5039 filler material. Weldments with 5183 filler material will be made during the next reporting period for comparison to 5039 filler material welds. It was determined that the optimum joint design for the one-inch thick material, a double-U with a 1/8-inch land, will not be satisfactory for the two-inch thick material due to inadequate head clearance. Additional panels will be prepared with larger included angles.

Investigations have continued in the determination of the joint characteristics of aluminum alloys 2014-T6 and 2219-T87 welded in the flat position while passing a coolant ($LN_2$) through the back-up bar. Panels of 2014-T6 were welded with and without cryogenic cooling while monitoring gage lengths during the heating and cooling cycles in order to determine if differential stresses existed. No detectable difference was found. Additional methods are being studied that will permit more accurate gage length monitoring.

Studies have continued in the comparison of the mechanical properties metallurgical characteristics of weldments in aluminum alloy 2014-T6 (1/8-inch thick sheet) made by using the TIG process with filler wire 2319, 4043, and M-934. Mechanical testing of the tensile specimens will be continued through the next report period. Also, samples have been prepared for metallographic examinations.

The evaluation of the weldability of Armco stainless steel 21-6-9 has continued. Radiographic inspection of the welded panels was completed, and on the basis of weldment quality, sections were selected for fabrication into tensile specimens. The Houldcroft tests were completed during this report period. These tests are being conducted to determine if hot cracking of this alloy is possible by extreme variations in weld parameters. No cracking was evident in any test weld sample. Ultimately, the mechanical properties (ambient and cryogenic) and stress corrosion characteristics of the weldments will be determined. Also, metallographic studies will be made of the weldments.

Investigations have continued in the evaluation of the weldability of Inconel 718 alloy after subjection to various solution anneal/aging cycle combinations. Houldcroft test specimens were received, and processing of these specimens will start during the next report period. From the results of the Houldcroft tests, the most readily weldable material resulting from specific heat treat cycles will be selected for determination of the weld mechanical properties at ambient and cryogenic temperatures. Also, the stress corrosion characteristics of the weldments will be determined for material displaying the most favorable weldability with respect to preweld heat treatment.

K. Development of Porcelain Enamel Thermal Control Coatings

Efforts have continued to develop porcelain enamel thermal control coatings. Present work is directed toward the development and application of white porcelain enamels to 3-mil aluminum foil. Difficulties have been encountered in obtaining the desired opacity. The temperature at which the enamels mature, 538°C (1000°F), is not nigh enough to produce opacity by crystallization of the glass frit, which is the primary constituent of the porcelain enamels. Additions of opacificiers, e.g., titanium

dioxide, in sufficient quantities to produce highly opaque enamels result in a semi-glassy surface rather than the desired glassy surface. Efforts to develop highly opaque enamels with glassy surfaces will continue.

L. Evaluation of Alloys

Shear tests were performed on specimens of A-286 material machined from a 1.5-inch diameter bar which had been solution treated at 1650°F (899°C) for 1-1/2 hours. Additional specimens were also solution treated at 1800°F (982°C) for 1-1/2 hours. These two groups of specimens were oil quenched from the solution treatment temperatures, then age hardened at 1325°F (718°C) for 16 hours, and air cooled.

Test results for the double shear tests are as follows:

| Solution Temp. °F (°C) | Ultimate Shear Strength (ksi) | 0.2% Yield Shear Strength (ksi) | Number of Tests | Test Temp. °F (°C) |
|---|---|---|---|---|
| 1650 (899) | 99.3 | 58.3 | 4 | 75 (24) |
| 1650 (899) | 127.4 | 76.8 | 4 | -320 (-196) |
| 1800 (982) | 102.8 | 61.0 | 4 | 75 (24 |
| 1800 (982) | 128.7 | 74.4 | 4 | -320 (-196) |

M. Investigation of Thin Film Dielectrics

The study of the effects of sputtering parameters for Teflon thin films has been completed. The results of these investigations show that film thickness is dependent on sputtering pressure producing a peak deposition rate at 60 microns (argon pressure). Applied RF voltage also produces a peak of deposition rate at approximately 1,200 volts. Interelectrode spacing, with other parameters adjusted accordingly. Determination of the electrical properties of these samples is in progress.

N. Investigation of Neutron Radiography

A program has been initiated jointly with the Quality and Reliability Assurance Laboratory to develop neutron radiographic equipment and techniques suitable for the inspection of launch vehicles and spacecraft materials and components. The purpose of this program is to develop techniques to allow the detection of flaws and the inspection of areas that are beyond the capabilities of existing X-ray techniques. Approximately half of the water tanks have been installed, and the beam-hole passageway has been manufactured by the Development Shop to allow the beam tube of the ion accelerator to penetrate the water tank shielding. Construction of the lead brick shield is also progressing in a satisfactory manner.

O. Study of Computer Enhancement of Radiographic Images

Computer enhancement of film images has great potential for improving radiographic technology. These enhanced images clearly show very fine cracks in the fused materials of weldments. The Jet Propulsion Laboratory and Information International, Incorporated are working with personnel at this Center in an effort to evaluate the new technology. Radiographs made here have been enhanced in a satisfactory manner at the indicated locations. Recently, additional enhanced radiographs have been received from Jet Propulsion Laboratory. The quality of these radiographs is outstanding.

P. Evaluation of Seals on Anodic Coatings by the AZTEC Method (Z Scope)

A program to evaluate various "seals" for anodized aluminum by the Aztec method (Z Scope) is continuing. Panels of alloys 6061-T6 and 2014-T6 were anodized, sealed by various methods, and electrical impedance values for the various seal coatings were determined by the use of Z Scope. The panels were subsequently exposed to a corrosion environment (one group in the salt spray and one group in humidity cabinet). The results of the salt spray and humidity tests will be used as a criteria for evaluating the impedance values obtained by the Z Scope. After about a week of exposure time, some salt spray panels showed a considerable amount of corrosion and some Z Scope values have been correlated successfully with the results of the corrosion test. In general, however, the tests have not progressed to the point where a complete evaluation can be made. No corrosion has occurred on any of the panels exposed to the high humidity environment.

Q. Specification Review

The following documents and specifications were reviewed and comments were forwarded as appropriate to cognizant offices and personnel:

1. CP114A 100 0026C, Revision C for MDA, AAP-2, Preliminary Copy dated June 7, 1968, Part I, End Item Detail Specification EI014000A.

2. MDC, STP0302, "Anodic Coatings, for Aluminum and Aluminum Alloys (OWS)".

3. Air Lock MDC Specs (reviewed only for vendor capabilities) P.S. Numbers 12025, 12300, 12301, 12302, 12304, 20500, 20501, 20502, 20505, 20531, 20590, MMS's 602, 603, 604, 605, 607.

4. NR Specification MA0601-002, "Installation of Threaded and Collared Fasteners for Saturn S-II."

5. Proposed MSFC Standard 486, "Standard Threaded Fasteners, Torque Limits for," dated May 24, 1968.

6. MSFC-SPEC-143, "Fittings, Flared Tube, Pressure Connections."

7. Marquardt Specification MPS-704, entitled, "Heat Treatment of Aircraft Steels and Heat Resistant Alloys."

8. MPS-1601, "Fusion Welding of Steels and Corrosion and Heat Resistance Alloys," dated August 26, 1959.

9. MPS-1609, "Electron Beam Welding, dated June 9, 1967.

10. MPS-1622, "Weld Procedure for 446 Stainless Steel Valve Bodies," dated June 11, 1968.

11. MPS-1611, "Fusion Welding Operators' Qualification," dated June 5, 1963.

12. MPS-1621, "Certification of Electron Beam Welding Machine Operators," dated June 14, 1966.

13. MPS-1623, "Hardness Welding of Solenoid Valve Armatures," dated July 8, 1965.

14. MPS-1624, "Qualification of Electron Beam Welding Machines," dated June 14, 1966.

R. Literature Survey

Surveys of the pertinent literature have been initiated and are continuing on the following subjects:

1. Radiation effects on engineering materials
2. Vacuum effects on engineering materials
3. Lubricants and lubricity
4. High and low temperature resistant polymers
5. Stress corrosion on structural alloys.

J. E. Kingsbury

MONTHLY PRODUCTION REPORT

MATERIALS DIVISION

JULY 1, 1968 THROUGH JULY 31, 1968

I. Radiography

Thirty-seven miscellaneous parts, components, and test specimens were inspected radiographically during this report period.

II. Photography

| | Negatives | Prints | Other |
|---|---|---|---|
| Engineering Photography | 118 | 620 | |
| Metallography and Fractography | 157 | 350 | |
| Miscellaneous Photography Processing, Copywork, etc. | | | 7 |

III. Metallurgical and Metallographic Testing and Evaluation

A. At the request of the Quality and Reliability Assurance Laboratory, evaluation tests were made on several acid etch mixtures for stainless steel. Several mixtures of nitric and hydrofluoric acid in various concentrations did not effectively etch (remove a significant amount of metal) samples of stainless steel. However, another mixture composed of glycerine, nitric and hydrochloric acid (called glyerigia) did remove a significant amount of metal (0.0007 inch in 10 minutes) in a reasonable amount of time.

B. An aluminum container and a variety of miscellaneous hardware items for the human effort studies were TIG welded in support of the Vehicle Systems Division.

C. Several aluminum components were joined by the manual TIG method for a test fixture to be used in the AAP-ATM project in support of the Vehicle Systems Division.

D. At the request of the Aero-Astrodynamics Laboratory a material selection was made for a shearing die to puncture diaphragms in the wind tunnel.

E. Assistance was provided to the Propulsion Division in the determination of spring rates for various bellows assemblies in existing propulsion systems.

F. Assistance was provided to the Quality and Reliability Assurance Laboratory in establishing the properties and degree of degradation of 60 tin-40 lead solder joints at elevated temperature.

IV. Spectrographic Analyses

Four hundred and eighty-one determinations were made by spectrographic analyses and two hundred and seventy-six standard determinations were made.

V. Infrared Analyses

Ten determinations were made by infrared techniques on a variety of materials including insulations, contaminations and residue specimens, and complex chemicals.

VI. Chemical Analyses

| | Determinations |
|---|---|
| Solvents for moisture content | 12 |
| Nitrogen tetroxide for | |
| purity | 2 |
| water equivalent | 2 |
| nitric oxide | |
| Polymeric specimens for | |
| carbon | 4 |
| hydrogen | 4 |
| silicon | 4 |

VII. Physico Chemical Analyses

| | |
|---|---|
| Density of RP-1 | 34 |
| Viscosity of Water with 2000 ppm Aerosol MA | 3 |
| Mass spectral analyses of gas for | |
| hydrogen | 20 |
| nitrogen | 4 |
| carbon monoxide | 2 |
| total hydrocarbons | 2 |
| Chromatographic analyses of liquid hydrogen for | |
| para hydrogen | 12 |

VIII. Rubber and Plastics

| | Items |
|---|---|
| molded and extruded | 296 |
| cemented | 20 |
| coated | 2 |
| fabricated | 2 |

IX. Electroplating and Surface Treatment

| | |
|---|---|
| electropolished | 6 |
| nickel plated | 1 |
| gold plated | 1 |
| stripped cadmium plate from | 15 |
| chromic acid anodized | 12 |
| acid cleaned | 5 |
| mechanically polished | 5 |

X. Development Shop Production

A. A total of 2,446 hours direct labor was utilized during this period for machining, fabricating, and welding.

B. Eight hundred and twenty-eight man-hours, approximately 34 percent of the total man-hours, were expended on work orders listed below.

1. Flange Assembly

The flange assembly has been completed and delivered.

2. Vent Disconnect Assembly

The vent disconnect assembly has been completed and delivered.

3. MSFC Experiment #8

Components for MSFC Experiment #8 have been completed and are ready for assembly.

4. Light Gas Gun Components

Components for the light gas gun have been completed and delivered.

5. Cryogenic Test Tank Modifications

The cryogenic test tank has been completed and delivered.

6. Gears for Testing

Gears of laminated material have been completed and delivered.

XI. Miscellaneous

A. Twenty-five pounds of 2024 aluminum rivets and one lot of vanadium nitride powder were heat treated during this report period.

B. Forty pieces of high strength steel wire were rolled, annealed, and roll pressed.

C. Five gallons of X-94 rubber cement were prepared for Manufacturing Engineering Laboratory.

D. Fifty materials were evaluated for sensitivity when in contact with liquid oxygen in accordance with the requirements of MSFC-SPEC-106B.

E. Thirty-one determinations of absorptivity and thirty-five determinations of emissivity were made during this report period on various commercial and experimental thermal control materials.

F. Thirty-one thermal property determinations were made including such tests as differential thermal analyses, differential scanning calorimetry, thermal gravimetric analyses, thermal conductivity, etc.

G. At the request of the Quality and Reliability Assurance Laboratory an analysis was made of a whisker observed on a transistor can. No diffraction patterns were obtained. Based on this, these whiskers appear to be an amorphous material with a relatively high melting point.

## XII. Publications

None.

J. E. Kingsbury

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-A-68-7

# MONTHLY PROGRESS REPORT
# ADVANCED STUDIES OFFICE
(July 1, 1968, Through July 31, 1968)

## ADVANCED PROGRAMS

### I. Launch Vehicles

#### A. Pressure-fed Launch Vehicle

Design data on the four-module first-stage pressure-fed vehicle configuration have been finished. All performance iterations have been completed and the final configuration and weights prepared. Viewgraph illustrations were prepared summarizing both these data and the background data leading up to the four-module first-stage vehicle design and the parametric design data on a typical pressure-fed module. The parametric data show the impact on module performance of number of engines, diameter of the module, strength-weight ratio of tankage material and tankage configuration.

Initial estimates have been made of optimum propellant loading, propulsion characteristics, and weight of a vehicle which consists of a pressure-fed first stage and the S-IVB as a second stage. These estimates have been made for configurations having a four-module first stage and a single-module first stage; performance of the single-module first stage vehicle is approximately 10 per cent higher for a 100-n.-mi.-orbit mission.

A status briefing on the PFLV study was given to the Director of the Advanced Systems Office on July 10, 1968. A memorandum for record (R-P&VE-AV-68-94, dated July 12, 1968) presenting the viewgraphs used in the briefing has been published. The memorandum

describes, in addition to the vehicle design and performance results, a "Pressurization Test Program" for concept verification of the use of fuel rich or oxidizer rich gas generator exhaust to pressurize the fuel tank and oxidizer tanks, respectively. Pending a decision by MSFC management concerning this MSFC test program, no additional effort will be expended on this study, other than documentation.

A summary report prepared by BECO covering results of the shrouded nozzle study and computer program users guide has been received and is being reviewed. No further effort is planned on this study.

The current effort on the Pressure-fed Launch Vehicle study consists primarily of documenting and summarizing design results which were generated during the last several months. This documentation effort, involving the support contractor, is scheduled to be completed about the middle of August.

B. Launch Vehicle Utilization Studies

The initial Phase I of the study of the Titan III launch vehicle applications was initiated. This phase is concerned with producing a consistent data package for mission planning purposes and includes both two- and three-stage configurations of the approved Titan III-A, -B, -C, -D, and -M vehicles, as well as the advanced Titan III-F, -F/LDC, and -G vehicles. The technical portion of the study concluded July 31 with the documentation expected soon.

Phases II and III of the original program have been combined into a single phase which will begin immediately and continue through the end of the year. The objectives of the modified program are the following: (1) generate weight summaries, configuration drawings, propulsion system summaries, and launch vehicle systems descriptions for nine additional launch vehicles; (2) determine payload to low earth orbit for selected two-stage vehicles; (3) determine payload to synchronous orbit, lunar injection, and planetary injection for selected three-stage vehicles; and (4) define the Titan-L configuration. For program purposes, emphasis and attention to detail is to be stressed for the Titan-M, -F, -F/LDC, and -G. In addition, the current technical directive supporting this effort has been amended reflecting the program changes in a manner that will best utilize support contractor resources for the remainder of this calendar year.

C. Nuclear Vehicle Studies

The effort on the nuclear vehicle mission analyses was reviewed and adjusted to reflect new objectives. In this regard, a revised program has been prepared which will emphasize examination of "earth-centered" missions utilizing the uprated NERVA I engine. In addition, the current technical directive supporting this effort has been amended reflecting the program changes in a manner that will best utilize support contractor resources for the remainder of this calendar year.

An estimate is being made of performance contribution due to nuclear engine aftercoolant propellant flow. Data on two aftercooling modes (continuous flow and pulsed) have been obtained and are being compared. Results from this study will be used to improve estimates of nuclear stage performance when used in a restart mode.

II. Earth Orbital

A. Saturn V Workshop

1. Space Station Program Planning Studies --- As previously scheduled, the NASA Headquarters Space Station Planning Exercise was to finish at the end of June with presentations by the participating Centers - MSFC, MSC, and LaRC. NASA Headquarters was scheduled to go to the Bureau of the Budget with a preliminary project plan during July, and the recent studies by the Centers were to form the basis for that plan. The MSFC inputs to this exercise were documented in a Program Plan, and a Detailed Briefing Document was transmitted in draft form to Mr. Mathews on June 28, 1968.

Presentations were made by MSFC, MSC, and LaRC to Messrs. Mueller, Mathews, Donlan, von Braun, Draley, and Hodges at NASA Headquarters on June 28, 1968. LaRC proposed an approach to the Intermediate Space Station which involved a one- to two-year, three- to six-man, hybrid-type station with selected new subsystems in 1973-74, followed by a 260-inch, two- to five-year, six- to nine-man hybrid station in 1975-76. Stations would be launched on Intermediate 20 (S-IC/S-IVB) launch vehicles and the major experiment program would be developed in modules to be brought up separately.

MSFC proposed a 260-inch, two-year, six-man station in 1974-75 (Enclosure 1) made up of two 3-man hybrid units with most experiments flown as separate modules. The program (Enclosure 2) shows that the six-man station (two-, three-man units) would be preceded by an early three-man step in 1973, having an AM/MDA systems unit with a new single three-man crew module. Saturn V was proposed to launch all stations although the Intermediate 20 was considered as a valid candidate. LaRC expressed full concurrence and support of the MSFC proposed approach.

MSC proposed 180-inch-diameter modules launched by Saturn IB vehicles with in-orbit docking and interfacing to establish a three-man station with selected new subsystems in 1973-74. A six-man station would evolve through in-orbit build-up and in the 1975-76 time frame larger modules (as yet undefined) could be flown up on the Saturn V. All studies considered the Saturn IB and Titan III-M as potential logistics carriers and proposed developing some new type of logistics spacecraft. In Mr. Mathew's management critique, subsequent to the briefing, the discussion centered around use of the Saturn IB as the carrier vehicle. Both Mr. Mathews and Dr. Mueller strongly advanced this approach of using 260-inch modules, if feasible. MSFC argued against the use of extensive in-orbit interfaces which are associated with the orbital assembly of small modules. Also, we stated that it did not appear reasonable to fly major station elements on the Saturn IB for the type station desired; however, the Centers were still requested to meet with Mr. Mathews on July 8, 1968, to discuss their thoughts relative to this approach.

In support of this request, a station concept (configuration, arrangements, weights) which could be launched on the Saturn IB vehicle was developed. These data were presented to Mr. Mathews on July 8. This concept contains a crew/experiment support/control compartment to be launched on the Saturn IB and a subsystems unit to be launched on a separate Saturn IB. (A subsequent weights analysis was completed which indicated the subsystems unit would require two Saturn IB launch vehicles.)

At the July 8 meeting, Mr. Mathews indicated his desire to continue assessing both Saturn IB and Saturn V launched stations. He requested that each Center review the draft Program Memorandum prepared by Bellcomm (which currently contains both launch vehicles as options) and work together to resolve weight differences on the various proposals. He further requested that MSFC continue to study the Titan III-M as a

logistics carrier and that MSC continue to study the logistics spacecraft approaches. Indications were also given that work statements, of moderate funding requirements, should be submitted on selected problem areas (not overall systems studies).

A draft of the preliminary program memorandum for the Bureau of the Budget (compiled by Bellcomm for Headquarters) was reviewed and comments were forwarded to R-AS. R-AS compiled the comments and forwarded them to Mr. Lord of NASA Headquarters. A major rewrite was recommended to properly relate such a program with currently planned manned space flight in the 1970-73 time frame.

An attempt is being made to arrange a meeting, possibly at MSC, to discuss weight estimates developed by LaRC, MSFC, and MSC on the intermediate stations. Concurrently, arrangements are being made for a few individuals from MSFC to visit LaRC to discuss their subsystems related research work.

2. $B_o$ Configuration --- The S-IVB flight stage designed as the backup for a wet workshop launched on Saturn IB has been examined for potential conversion to a dry launch configuration for Saturn V. Analysis of the removable hardware has been completed. The next step will be to determine the applicability of the stage to accommodate the necessary Saturn V Workshop hardware. The analysis will also determine the cost, schedule, and level of difficulty to convert the stage for Workshop use.

Results of both the S-IB/S-IVB modifications to fly on the Saturn V, and the utilization of the Saturn V/S-IVB for use as a dry OWS are described in memorandum R-P&VE-AV-68-95, dated July 16, 1968. A draft of the remaining analyses on the S-IB/S-IVB modifications for accommodating Saturn V Workshop hardware will follow. A summary of the MDC technical memorandum, number 440, "AS-210 Workshop Alternate Mission Application," is being prepared.

Vehicle mass characteristics have been generated and provided to R-AERO-X for a Saturn V/OWS configuration having a payload of 100,000 pounds above the S-II stage. This is considered to represent an upper payload limit with respect to maximum experiment and OWS weight growth. Previous analyses have been based on a lower limit payload of 63,500 pounds. On completion of the vehicle control analysis by R-AERO-X for the 100,000-pound payload case, the vehicle structural loads will be evaluated and compared to data generated previously for the 63,500-pound payload case.

3. Resupply Logistics --- Discussions were held with R-AS concerning the resupply logistics effort in support of the Saturn V Workshop study. It was agreed that this Office would provide vehicle mass characteristics data, structural loads data, S-IVB stage modifications, and a definition of the CSM to be used for logistics missions. A memorandum, R-P&VE-AV-68-87, dated June 21, 1968, provides data concerning one means of furnishing electrical power via "dormant fuel cells" for extension of lifetime from 56 to approximately 100 days.

4. Nuclear Power System Integration Study --- MSFC Laboratory study contacts for the joint NASA-MSFC/AEC-Atomics International study of a nuclear electrical power system for Saturn V Workshops met July 17, 1968, to discuss laboratory participation in the study. Attendees included representatives from R-P&VE, R-ASTR, R-AERO, and R-QUAL. Saturn V Workshop configuration control will be the primary responsibility of R-P&VE. A meeting with AEC and AI representatives was planned for August 1, 1968, at MSFC for an exchange of preliminary technical information and discussions of study design guidelines and approaches.

B. Earth Orbital Experiments

In a recent meeting, representatives of R-ASTR, R-SSL, and this Office discussed the status of the Relativistic Redshift Experiment Phase I Development Program. Diagnostic vibration testing of the R&D maser is currently being performed by Hewlett-Packard and a representative of R-P&VE-SV will monitor the first tests. R-ASTR stated that they are currently considering gravity gradient systems for attitude stabilization. It was suggested and agreed that both gravity gradient and inertially oriented, active attitude control systems should be investigated, in parallel, until a determination of the effect on solar panel size and arrangement, and thermal environment can be made. Preliminary analyses to determine a suitable approach to providing the required thermal environment to the maser was planned to be performed by this Office; however, with the phasing out of BECO support to this Office, it is doubtful that this can be accomplished in the manner desired. An assessment of what can be accomplished with the remaining resources and whether it will be satisfactory is being made.

III. Lunar

The Mobility Test Article (MTA) Test Program began on July 15, 1968, at MSFC and is presently in progress. Test Laboratory is providing personnel and equipment for this test. All three vehicles are on the test course; however, problems with the generator, mounted on the

chase vehicle which provided mobility power for the MTA's, and problems in the steering logic circuits of the Bendix MTA have prevented any actual data acquisition. It appears now that data acquisition will be slightly delayed. The test program should be completed before October 1, 1968. BECO personnel will be involved in the BECO LSSM Mockup testing and in the data reduction for all the vehicles.

In response to a request for information on the test program from the Huntsville Times, personnel from this Office briefed PA-M on the program. Since Dr. von Braun has not driven the GM/MTA and had expressed a desire to do so at the demonstration of the Bendix MTA and BECO LSSM Mockup two years ago, a demonstration at the test site is being arranged for him. Mr. Herbert Schaefer, R-AS, the COR for the MTA program, is coordinating the demonstration with the Director's Office. PA-M will film the demonstration for a tentative local TV and Press release.

A work statement has been written and submitted to NASA Headquarters, at their request, for a three-phase contract with General Motors AC-DRL to define a test program and the vehicle modifications necessary for future remote control driving tests of the GM-built MTA at MSFC. Phase I would be the definition of the test program; phase II would be actual vehicle modifications; and phase III would be assisting MSFC in conducting the test program.

IV. Planetary

The parametric study of unmanned scientific payloads to Mars has been completed and the results are documented in report TN-AST-274. The objective of this study was to define the various payloads which can be orbited or landed, the scientific instruments to be included in these payloads, and the data return that can be expected assuming various launch vehicle capabilities. This study concluded that for missions flown between 1970 and 1980 the payload to either orbit or to the surface is largest in 1971 and 1979 and smallest in 1973 and 1975, with 1977 being almost as good as 1979. Optimum trip times were approximately seven months in 1971 and 1973 and approximately twelve months in 1975, 1977, or 1979. Of the mass injected from earth only 75 to 90 per cent arrives in the vicinity of Mars as useful mass and only one-third of this can be placed in orbit around Mars. Approximately 10 per cent of the orbit mass can be landed on the Mars surface as useful scientific payload.

V. General

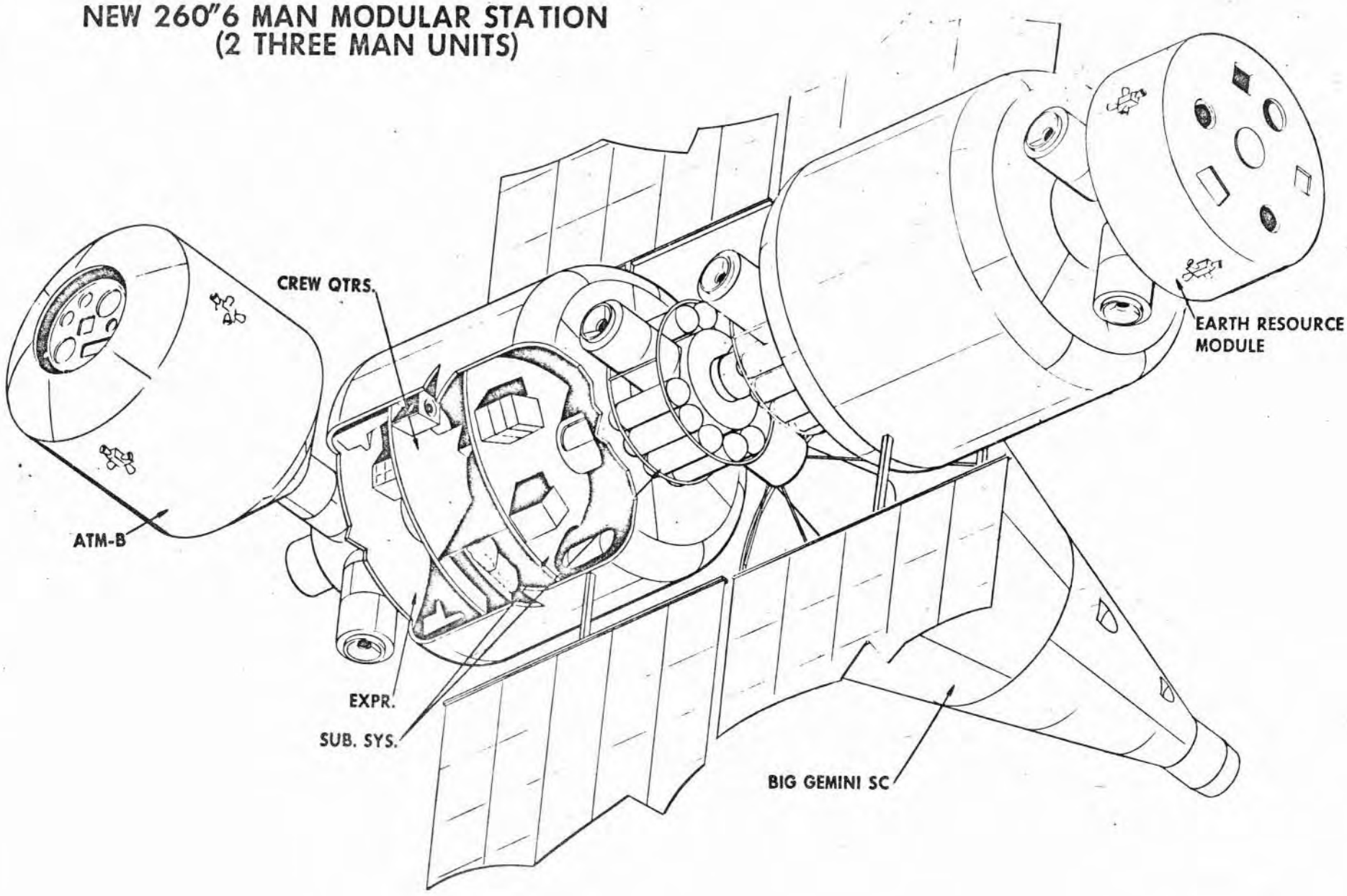
ART/SRT Requirements

The "Preliminary Unmanned Planetary Exploration Mission Requirements" report has been distributed to members of the SRT working groups and Mr. Moore's (R-ASTR-N) project group for advanced computer development. A format for describing individual, specific SRT tasks was agreed upon by R-P&VE-A, R-ASTR-A, and R-AERO-X. This will be used in compiling the SRT requirements documents.

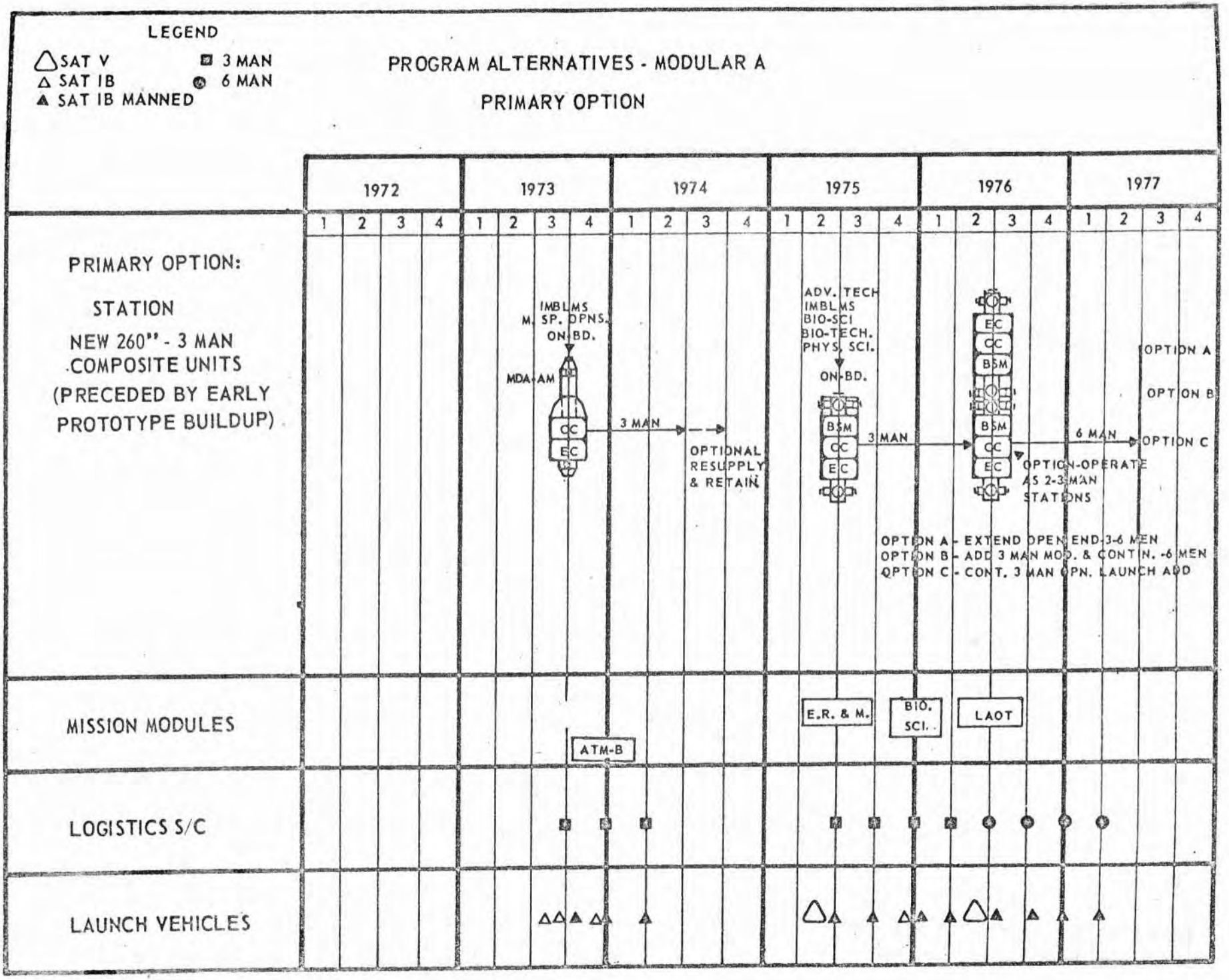
J. W. Heyer
for Charles L. Barker, Jr.

Enc 1

# NEW 260"6 MAN MODULAR STATION
# (2 THREE MAN UNITS)




MSFC-68-R-P&VE-125


LEGEND
SAT V
SAT IB
SAT IB MANNED
3 MAN
6 MAN
PROGRAM ALTERNATIVES - MODULAR A
PRIMARY OPTION
1972
1973
1974
1975
1976
1977
1 2 3 4
PRIMARY OPTION:
STATION
NEW 260" - 3 MAN
COMPOSITE UNITS
(PRECEDED BY EARLY
PROTOTYPE BUILDUP)
IMBLMS
M. SP. OPNS.
ON-BD.
MDA-AM
EC
QC
3 MAN
OPTIONAL
RESUPPLY
& RETAIN
ADV. TECH
IMBLMS
BIO-SCI
BIO-TECH.
PHYS. SCI.
ON-BD.
BSM
3 MAN
6 MAN
OPTION A
OPTION B
OPTION C
OPTION-OPERATE
AS 2-3 MAN
STATIONS
OPTION A - EXTEND OPEN END 3-6 MEN
OPTION B - ADD 3 MAN MOD. & CONTN. -6 MEN
OPTION C - CONT. 3 MAN OPN. LAUNCH ADD
MISSION MODULES
ATM-B
E.R. & M.
BIO. SCI.
LAOT
LOGISTICS S/C
LAUNCH VEHICLES

GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-R-P&VE-V-68-7

MONTHLY PROGRESS REPORT

VEHICLE SYSTEMS DIVISION

(July 1, 1968, through July 31, 1968)

SATURN IB

General

A. SA-205 Flight Sequence

Two Engineering Orders (EO's) providing changes to the SA-205 in-flight sequencing of the S-IVB propellant utilization (PU) system for mixture ratio shifts were released. These changes resulted from the recent decision to fly with the PU system in an open-loop configuration and to provide additional orbital venting of the S-IVB $LH_2$ tank because of the additional propellant residuals which will be left onboard.

B. Technical Checklist

The last revision (18) of the Saturn IB Technical Checklist was sent to Industrial Operations (IO) for approval.

SATURN V

I. S-IC Stage

A. Hydraulic Supply and Checkout Unit (HSCU)

1. The pumps of the S-IC HSCU in Mobile Launcher (ML)-1 have experienced approximately 310 hours of operation. After the launch of SA-503, when approximately 500 hours of operation will have been accumulated, it is conditionally planned to remove the pumps for reconditioning. The option on the pump teardown is to extend the operational time to 750 hours (one more launch). The decision will be based on the condition of the systems development facility pumps which are scheduled for reconditioning in the near future.

2. A survey of the drawings (75M20036) for the KSC maintenance kit, involving attachment to the HSCU for pump removal, has indicated that several problems may exist. A modification to the HSCU will be required to provide attach points for the maintenance kit.

3. As a result of the above survey and coordination with Kennedy Space Center (KSC) operations personnel, it has been established that an exercise to "proof" the kit installation is in order. KSC will notify this division when this effort is scheduled so that personnel may be dispatched to assist in the identification and correction of problems.

4. A series of test requirements have been prepared for the HSCU at the systems development facility (SDF) to accomplish the following:

Inadvertent closing of antidrain back valve during operation of the HSCU.

Effect of different control pressure switch settings on antidrain back/relief valve operation.

Repeatability of HSCU main system relief valves.

Noise level reduction by use of shower head orifices.

Main hydraulic pump longevity.

The SDF has prepared procedures for these requirements; tests have been scheduled to begin on August 6, 1968.

B. Interlocks

1. EO 14 on the S-IC Stage Interlocks document and EO 6 on the Saturn V Automatic Sequence document were released to change specified start time of engine 1 because of its replacement with a new engine with different starting characteristics.

2. EO 15 on S-IC Stage Interlocks document was released to reflect changes in lox and RP-1 prepressurization mechanical ground support equipment (MGSE) sequencing. This EO defines the electrical support equipment (ESE) operational requirements necessitated by changes to the MGSE which was modified to properly maintain the required propellant tank ullage pressure during prelaunch activities on vehicles with reduced ullage space.

II. General

A. Water Deluge for Hypergolic Spillage

1. KSC resubmitted Interface Revision Notice (IRN) 12 to 65ICD9030 on July 19, 1968, approximately 7 weeks after MSFC had failed to concur in the initial submittal. This IRN provides for a manifold and nozzle arrangement to dump 1500 g.p.m. of water at 80 p.s.i. in the instrument unit (IU), S-IVB forward area to dilute and wash down a major hypergolic spill.

B. SA-503 (Manned) Flight Sequence

1. This laboratory's latest requirements (MSFC drawing 10M30629) for the SA-503 (manned) flight sequence program was transmitted to Astrionics Laboratory.

2. EO 1 was also released to the document to update the sequence to the latest flight performance prediction and to provide for an early cutoff of the center engine on the S-IC stage to reduce the load placed on the spacecraft during the stage engine cutoff sequence.

C. Contamination Study

The Contamination Study on the Saturn V vehicle, ground support equipment, and facilities has been replaced. The Saturn V Contamination Study analyzed Unsatisfactory Condition Reports (UCR's), specifications, Interface Control Documents (ICD's), and researched applicable system schematics to verify the system design integrity. From the conclusions and recommendations of this report, it is apparent that no new design solutions are required for Saturn V vehicles; however, it should be stressed to all contractor operations personnel that care must be taken in the handling, modification, and maintenance of contamination susceptible systems.

## APOLLO APPLICATIONS PROGRAM (AAP)

I. Orbital Workshop (OWS)

A. Neutral Buoyancy Trainer

A meeting was held with representatives of the Martin Marietta Corporation to initiate preparation of a specification to define hardware and program requirements and configuration of the OWS Neutral Buoyancy Trainer. Since the information requested by the Engineering Management Office encompasses more than an end item specificaiton, a model specification was proposed.

B. Workshop Attitude Control System (WACS)

1. The WACS Research and Development Plan has been approved and distributed.

2. The WACS Development Test Plan, 10M32964, was completed on July 19, 1968.

II. Multiple Docking Adapter (MDA)

A. Documentation

1. The AAP-2 corollary experiment second generation drawings have been completed.

2. A layout was made showing the MDA window in its new location, revealing an interference with the MDA/LM docking target. A redesign of the docking target to avoid this interference was requested.

3. Up-to-date drawings concerning the MDA dynamic test article were packaged and sent to Martin Marietta Corporation.

B. Experiment Hardware

The status of the MDA experiment hardware procurement was reviewed. It was found that an essentiality statement must be forwarded to NASA Headquarters for evaluation and approval. This delay will extend the delay of the hardware test program a minimum of 2 months.

C. Schedules

1. A draft of Section I to the MDA Research and Development (R&D) Project Schedule was completed and submitted to the Engineering Manager.

2. The preliminary MDA Ground Support Equipment (GSE) schedule was completed and submitted to the Engineering Manager and MGSE Project Engineer.

III. Apollo Telescope Mount (ATM)

A. Documentation

1. Engineering Change Request (ECR) AGMM-001, requesting the location of the rate gyro package from the spar to the rack, was reviewed. A sketch was prepared which shows the rate gyros installed on the rack. The canister location still has to be reserved for a set of rate gyros.

2. The assembly documentation for replacing the Harvard College Observatory (HCO) -C experiment by a modified HCO-A is being accomplished.

3. The ATM alignment matrix and alignment control drawing was revised to include the replacement of the HCO-C experiment by the HCO-A modified experiment. These drawings are being submitted to Astrionics Laboratory program manager for baselining and inclusion in the ATM specification.

4. A mechanical working mockup has been designed and parts have been fabricated for a quadrant of the ATM canister sun end. The mockup will simulate a film retrieval door as well as the sun end doors with all operating parts except a torque motor. The door sliding surface as well as all shafts and mechanical parts will simulate the flight configuration concept. Assembly of the mockup should be completed by August 15, 1968. The mockup will aid in final definition of the ATM canister sun end design.

5. A filter has to be installed in the canister nitrogen purge system. A layout has been prepared which shows the filter installed on the canister lunar module (LM) end. The filter is 4 inches in diameter, 18 inches long, and weighs 20 pounds.

6. ATM alignment control drawing 10M03736 has been updated to revision A.

7. The concept layout of the ATM assembly cover for transportation is approximately 90 percent complete.

B. Film Retrieval Simulation

A KC-135 zero-g evaluation of the ATM LM end workstation and release mechanisms for the HAO, GSFC, H$\alpha$1, and AS&E Film Cassette was conducted at Wright-Patterson AFB July 17 through July 19. Preliminary evaluation indicates that the GSFC, H$\alpha$1, and AS&E Cassette release mechanisms, doors, and locations are adequate. The HAO Cassette will require several modifications including a more positive detent for the "Lock" position, larger dowel guide holes, better electrical connector system, and a retainer to hold the lock release handle during cassette removal and replacement.

IV. General

A. Quarterly Review

Representatives of the division attended the AAP Quarterly Review held at MSFC on July 24 and presented the results of a trade-off study to determine whether the primary medical experiments and support hardware shall remain in the MDA after activation or moved into the OWS. In general, the AAP Program Director and the MSC personnel in attendance were not pleased with the results of this study. Due to comments made by Dr. von Braun who was present at the meeting, an action item was given to MSC to show why the medical experiments should not be moved to the OWS after MDA operation.

B. Flight Crew Training

Division personnel met with cognizant MSC personnel to discuss AAP flight crew training. MSC will fully define training support required for MSFC-responsible hardware. Preliminary indications are that MSFC will be required to supply system briefing, technical descriptive manuals, and system operating procedures.

C. Solar Array System (SAS)

The SAS Research and Development Plan has been approved and distributed.

## ADVANCED TECHNOLOGY

I. Experiments

A. Return Items for AAP-2 Experiments

Since no specific experiment return capability information is available regarding the AAP-2 Command Module, this division has prepared and transmitted to the Mechanical Panel a summary of AAP-2 Corollary Experiment return requirements so that action may be initiated to resolve these return requirements. This summary provides weight and volume requirements of the 22 Baseline Requirements of AAP-2.

B. Earth Resource Experiments

Physical integration requirements for incorporating six earth resource experiments on AAP-2 were presented to the Mission Requirements Panel at MSC on July 11, 1968. The presentation was a portion of an overall mission requirements presentation made to the Panel by the Earth Resource Experiments Working Group. As a result of this presentation, the Working Group was granted a spot on the AAP-2 Baseline Review agenda (July 23-24, 1968) to summarize the impact of integrating the earth resource experiments to AAP-2.

C. Auxiliary Lighting Requirements

1. Development of a portable auxiliary light seems necessary to support the photograph requirements of AAP-2 experiments in both the OWS and the MDA. Lighting tests in the OWS have been completed by MSC personnel in support of experiment M055, "Time and Motion Study," confirming the need for auxiliary lighting. Similar conditions are anticipated in the MDA.

2. The M055 tests established a minimum light level of 10 foot-candles on the photographic subject when using very high speed film. The present light levels at the experiment worksites in the OWS are generally less than 10 foot-candles. Radiation effects may prevent the use of the very high speed film. The use of slower speed film will require greater than 10 foot-candles lighting levels.

D. Baseline List of Experiments for the AAP-2 Mission

Division personnel assisted IO in producing baseline lists of experiments for the AAP-2 mission. Such assistance consisted of supplying experiment parameters for analysis with experiment selection criteria established by IO. Final selection of AAP-2 experiments will be made in the near future at NASA Headquarters by a fifteen-person committee of five each from MSFC, MSC, and NASA Headquarters.

E. Systems Design Test and Checkout Requirements (AAP-2)

The System Design Test and Checkout Requirements for the workshop attitude control system (WACS) AAP-2 has been completed and assembled under drawing 10M30827. This documentation will serve as a baseline for delineating to KSC the MSFC furnished test requirements specifications and criteria for the WACS mechanical and electromechanical systems under the MSFC and KSC subagreement. In addition, the documentation will delineate the measurement instrumentation program for testing as well as the design criteria for the associated GSE used in the accomplishment of these tests.

F. General

1. The "AAP-4 Prelaunch Sequence of Operations" MSFC drawing 10M30825, prepared by this division, in cooperation with Astrionics Laboratory, has been approved by the ATM Engineering Manager as a baseline for finalizing the AAP-4 prelaunch sequence of operations for the AAP-4 mission peculiar ground operations covering the period from arrival of the major assemblies and experiment equipment at KSC until the vehicle is launched. Major AAP-4 mission peculiar equipment arriving at the site include the lunar module ascent stage (LM-A), Apollo Telescope Mount (ATM)/Rack, Nosecone, Spacecraft Lunar Module Adapter (SLA), and Spacer.

2. Preliminary layouts defining the ATM mobility aid (astronauts) routing are being prepared. Analysis of the structure and discussions with MSC crew systems personnel indicate that the best initial approval would be to egress from the LM Extra Vehicular Activity (EVA) hatch then over the adjacent structural outrigger to the solar array backup structure to the LM end work station. Approximately one-third of the way between the LM hatch and LM end work station, a mobility aid system will be routed to the sun end work station. This routing will enable the astronaut to be guided through the solar arrays. Present plans are to make the system as mechanically simple as possible with little or no deployment by the astronaut required.

John O. Aberg

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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PR-P&VE-S-68-7

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MONTHLY PROGRESS REPORT

STRUCTURES DIVISION

(July 1, 1968 through July 31, 1968)

SATURN IB

Saturn IB System

Pull Test

The evaluation of AS-205 pull test has been completed. The average value of the strain-to-load constant was 59 lbs/-in/in as compared to 65 lbs/-in/in for AS-204. This difference was not due to a redistribution of loads as originally suspected, but it was due to a variation in the strain gages (gage factor, installation, etc.). This variation in strain-to-load constant illustrates the need to calibrate the gages prior to each flight. A pull test is the best means for calibration, since it provides an end-to-end check of the strain gage system.

## I. S-IC Stage

A meeting was held on July 16, 1968 to discuss the status and possible solutions for the lox and fuel tank baffle cracking problems. It was decided that the laboratory position would be to inspect the lox and fuel tank baffles on S-IC-6 after static firing. This information will be used to make a decision on S-IC-3 inspection requirements. As of this date, no inspection is required on S-IC-3. In order to gain more confidence in the Boeing stress analysis, MSFC has requested the Boeing Company to consider performing a structural test on either a full size ring baffle or scale model to determine the relative stiffness of a good ring versus a ring with complete baffle segments missing. This would involve loading a complete 360° ring with radial loads and measuring the radial deflections. The test would then be repeated with a baffle web or webs removed. A comparison of deflections would be a good indication of the validity of Boeing's stress analysis. While Boeing was gathering pertinent drawings and information required to verify the structural analysis in-house, it was discovered that the stiffener spacing on some of the lox and fuel tank baffles is actually 30°, approximately 100 inches. The Boeing analysis was based on 34-inch spacing in the fuel tank and 50-inch spacing in the lox tank. The Boeing Company was informed of this discrepancy immediately and they confirmed that the 30° spacing does exist on AS-504 and subsequent vehicles. The drawing system indicates the 30° spacing is effective on AS-501 and subsequent vehicles for the fuel tank and AS-504 and subsequent vehicles for the lox tank. This problem will be resolved, and Boeing is performing a new analysis to determine the effects of 100-inch spacing.

## II. S-II Stage

### A. Flexible Lines

In conjunction with North American Rockwell and Propulsion Division, the Vibration and Acoustics Branch made an assessment of the flexible lines on the S-II stage to determine which lines needed to be flow tested to confirm their integrity for flow induced vibration. The following criteria were used to determine which lines would not require flow testing:

1. Lines that have a flow duration of less than one second.

2. Lines having bellow liners and internal gimbal joints.

3. Lines having no flow condition.

4. Lines that have been analyzed to show no overlapping of the natural frequency and vortex shedding frequencies.

The number of lines requiring flow testing was determined to be two each of eight different bellow systems for a total of 16 flow tests. This testing is required to be completed by AS-503 Countdown Demonstration Test.

B. "A" Structure (402)

Testing began and has proceeded through a liquid nitrogen fill. Some cracks were experienced in the foam insulation in the bolting ring area during this cryogenic test. These cracks are attributed to the large amount of potting done in the area with a mixture of Narmco 7343 and foam dust. Present plans are to proceed into liquid hydrogen testing with the cracks. Ice formations were experienced in the forward skirt/ Y-ring area and consideration is being given to purging the area.

A noise hazard exists at the S-II-402 data trailer site during F-1 engine firings. During the last F-1 engine firing, Test Laboratory measured a sound level of 134 dB in the Data Acquisition System trailer. Vibration and Acoustics personnel are evaluating the data to determine if safety requires evacuation of the trailer during future firings of the F-1 engine. Because of the severity of its environment, Test Laboratory personnel are bracing the inside of the trailer to protect the data system from damage during future engine tests.

C. "B" Structure (401)

The forward skirt failed during testing with axial load and internal pressure. The hoop tension failure occurred in the skin splice and damaged the skirt extensively. A trip was made to North American to evaluate this problem and to study design modifications. Present plans are to modify the S-II-10 forward skirt and install it on the test article to test the redesign. The redesign will be effective for S-II-4 through S-II-10. Remaining vehicles have greater structural capability in this area.

D. "C" Structure (403)

An ECP to strengthen the S-II-4 thrust structure for engine-out capability was approved. The fix will be installed on the flight vehicles S-II-4 thru -10 as well as the "C" structure.

North American personnel have finished installing the flight fix on the "C" structure and testing is scheduled to begin August 12, 1968.

Boeing has received a partial review of strain instrumentation for assessing the amount of repair required on the strain gages, heater blankets, and deflection indicators to get the test structure in shape for data retrieval.

III. Saturn V System

A. Damper System

Coordination was continued with Kennedy Space Center for updating of the three systems. Components from ML-1 and ML-2 were returned to MSFC for updating of the redundant hooks open and closed switches.

Considerable corrosion was experienced on the damper cylinders in the qualification test program while exposed to a 10 day salt fog. Functional testing is continuing but corrective action with the vendor will be necessary.

B. POGO Fixes

The vibration data from F-1 POGO evaluation firings were reviewed at Rocketdyne to determine if a radically more severe vibration environment was generated by the F-1 "POGO fix" and to correlate the possible change in environment to the failure of the S-IC-PVC on the subject engine. Although only one measurement was available from the firings, this measurement indicated no significant variation over previous data. Therefore, the PVC failure cannot be attributed to an excessive or unusual environment caused by "POGO fixes".

In meetings between Structures Division, Propulsion Division, and the Boeing Company, the components and test program for qualification of the additional hardware required for "POGO fix" were determined. The specimens will consist of a prevalve dome and check valve, and a pneumatic panel.

C. Short Stack Structural Test at Wyle Laboratory (SSST)

1. Structures Division was represented in a meeting at North American, Downey and Wyle Laboratories, Huntsville concerning the "short stack" structural test to be done by Wyle. The stack consists of a load fixture to represent the command module, structural components of the service module and lunar module, the SLA, and instrument unit, an S-IVB forward skirt, and a simulated S-IVB $LH_2$ tank fixture. Preliminary test plans, loads, and instrumentation have been formulated and are being reviewed by all parties involved in the test.

2. R-P&VE-SS attended the July 12 SSST meeting at Wyle Laboratories where discussions centered primarily on proposed loadings and their application. Because some loading conditions proposed by Manned Space Center are equal to or greater than IU capability, and because the MSC loadings contain a degree of conservation, more realistic loadings should be established in order for the IU to have a reasonable chance of passing the test. In addition, since test sequencing is important, a preliminary test condition sequence has been determined, placing more severe tests at the end of the series. Several meetings were held during the period to define the P&VE position regarding acceptable loads for use in the SSST. R-P&VE-SL will establish acceptable loads for use in the test and R-P&VE-SS will examine these loads to insure that no adverse loads are applied to the S-IVB forward skirt or the I.U. A test sequence was established as the P&VE position for proper testing of the SSST. The testing should be done with static equivalent loads to simulate the dynamic environment to assure the most meaningful data is recovered. MSC wants to use dynamic lateral loading for the LEM superimposed on the static loads. The proposed test sequence has been forwarded to MSC for their review and comments.

3. a. IBM's instrumentation requirements for the SSST have been reviewed and agreed upon.

b. North American Rockwell's test plan using MSC dynamic loads for the SSST has been reviewed with the following major comments resulting:

(1) Proposed loadings appear to be higher than IU capability values in some instances.

(2) Adequate sequencing of proposed loadings and environments was not shown.

(3) No definition of the dynamic loadings in terms of equivalent static loadings that will be imposed on the structure were given, and consequently could not be evaluated. Also, no time duration was stated for the dynamic loads.

(4) No heat will be applied to the SLA, resulting in a condition at the IU/SLA interface which remains to be evaluated.

(5) No burst pressure will be applied to the IU resulting in a degree of conservation which has not yet been assessed.

## SATURN V SYSTEM

### Proof Load Damper Cylinders

The two cylinders that are used to actuate the damper to vehicle latch mechanism were proof loaded to 5,000 pounds. These cylinders were removed from ML-1 and were modified by Manufacturing Engineering Laboratory. Proof loading was required to verify that the cylinders would hold 5,000 pounds each when in the retracted or latch position. They satisfactorily held the 5,000 pound load.

## APOLLO APPLICATION PROGRAM

### I. Orbital Workshop Ventilation Fans

The results of the first phase of the OWS ventilation fan acoustic test indicated that the acoustic environment was less than what was anticipated. It has been determined that this discrepancy was due to improper wiring of the fans which resulted in low operating voltages at the fans. The tests were accomplished with an operating voltage from 21 to 22 volts. This resulted in a fan speed of approximately 4000 rpm. When the fan voltage was increased to the required 30 volts, the fan speed increased to 5400 rpm and the overall sound pressure level (SPL) increased by 4 dB. The speech interference level (SIL) is increased to 70 dB as compared to the 68 dB measured in the previous test. Further tests will be accomplished with proper fan voltage and speed.

II. Apollo Telescope Mount

A. Rack

The package of 27 drawings representing the solar array support ring was corrected in accordance with the drawing check and stress analysis results and returned for documentation release.

Detail design was initiated on the intercostal modifications that are required to insure clearance with the Perkin-Elmer roll drive and roll position indicator packages, and also initiated on the strut retraction system required at the LM-end work station. The layout for the acquisition sun sensor support structure was completed, while work on the sun shield layout was suspended until the requirements of the sun-end work station are available. A layout was also made defining changes required in the Perkin-Elmer launch lock fittings to insure an adequate attachment to the Rack.

B. Experiment Package

A decision was made by ATM management to substitute a modified HCO-A (S-055A) for the HCO-C (S-083) instrument. This decision will cause considerable redesign and redrawing of sun-end and spar details. The spar assembly and details have been returned to checking unit for release. The drawings, however, do not reflect the change in the HCO instruments. The LM-end integral machining drawings have been released to checking.

C. Rack Test Facility

The new drive bar assembly having the bronze reinforced teflon bearings has been tested in the unloaded condition with promising results. A design is being prepared for a bronze or brass-on-steel bearing which is expected to give better results and have a longer use period.

III. Multiple Docking Adapter

A. Skin Panel

The structural test assembly drawing, 30M14300, has been released with one window over port I and provisions in the skin panel for mounting a scientific airlock at position 3. If a window should be required at position 3 on the dynamic and flight articles, no requalification on the structural unit will be necessary. Drawings of the window assembly and details specifying a single pane of Corning 7940 glass will be advanced released soon to permit procurement in time for the structural test.

B. MDA Docking Ports

The design of the MDA pressure hatch test fixture has been completed. A work order has been initiated for the fabrication of one article.

Design ground rules have been established for the design of the hard cover over port No. 1. A design concept incorporating meteoroid protection and utilizing a noncontaminating separation system has been completed. A layout depicting the clearances between the cover and the internal structure of the payload shroud has been forwarded to the Aero-Astrodynamics Laboratory for a detail study of shroud clearances during shroud separation.

IV. S-IVB Stage

A. APS Testing

Tests of the APS "dummy" module were witnessed by Vibration and Acoustics Branch personnel at the Douglas Sacramento Test Center. All tests were completed with the exception of tests at revised sinusoidal sweep and random levels, which the contractor has only recently agreed to complete. Tests on the dummy module were to assure the adequacy of the test equipment and procedures, and to familiarize test personnel with the requirements for the live hypergolic system tests, which began July 29, 1968.

During the "dummy" tests, several structural and tubing failures occurred in the forward section of the module, making the validity of previous DEQ testing questionable, and raising doubts about the qualification status. As a result of specification review following the test failures, the Vibration and Acoustics Branch and MDC personnel have agreed upon revised APS module test levels, which will be incorporated into the test plans.

The dummy APS module tests also revealed test fixture and backup structure problems which led to modifications which greatly enhance the probability of success in the test of "live" modules.

B. Auxiliary Propulsion System

Detail drawings are being prepared for the APS support structure, insulation blankets and fairing. Schedule delays are anticipated in the near future due to several changes in the insulation requirements and the insulation purge requirements.

The structural design has advanced to approximately two months ahead of the rest of the design and the above changes are due to the lag in the system requirement definition.

V. Solar Array

The larger area concept for the solar panels has been developed. No further action can be taken until a decision is made to use the new panels or stay with the old ATM panels. Astrionics Laboratory has provided a solar array cable concept for a routing study. It appears that the cable will be routed along both edges of the panel.

VI. Nose Shroud

Preliminary layouts are being prepared for the two cylindrical sections of the nose shroud. Both cylinders are being designed to utilize existing Saturn V ring frames. Minor problems exist in the location and size of the access doors and umbilical plate and in the detail design and attachment of the ejection thruster.

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-68-7

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

July 1, 1968 through July 31, 1968

SATURN IB

I. S-IB Stage

A. S-IB-12 Static Tests Completed

A successful flight-duration static test of stage S-IB-12 completed the test series for this stage and concluded the static tests planned for S-IB stages. Bellows-type LOX seals were installed on all engines, and post-test inspection revealed no problems. The bellows LOX seal will be retrofitted on AS-205 at KSC. The launch configuration LOX seal drain temperature system (both engine mounted thermocouples and ground located cutoff circuitry) was also successfully tested.

B. Flight-Worthiness Verification Tests

H-1 engine H-7053 was subjected to 17 tests for a total duration of 2116 seconds. This fulfills the Model Specification requirements of 15 tests and 2025 seconds, and demonstrates the readiness of similar (age and configuration) engines on AS-205 for flight. Three discrepancies were reported; two were thrust chamber braze erosion and leakage. This is a usual occurrence for extended-duration testing and is field repairable. The third discrepancy concerned a self-induced, self-damped burst of instability which caused no damage. This occurrence, though not common, has occurred during previous engine tests with no damage to engine hardware or reduction in engine test life. Post-test checkout and hardware disassembly will be completed before the AS-205 launch.

II. S-IVB Stage

A. APS Propellant Loading Data

The APS propellant loading data was prepared for incorporation in the propellant loading document for AS-205 and subsequent. The

data includes the loading requirements in terms of expulsion bellows extension versus propellant temperature and usable propellant versus bellows extension.

B. Flow-Induced Vibration Calculations for APS Lines

Critical velocity calculations were completed for three different sizes of bellows lines in the auxiliary propulsion system. Results indicate that the velocity becomes critical at approximately 25 feet per second for liquids and 30 feet per second for gases.

C. Orbital Workshop (OWS)

1. 1800 $ft^2$ Solar Array Impact

Analyses were conducted which show that the larger solar arrays do not significantly affect the OWS thermal control system. The greatest effect noted by the change to larger solar arrays was a decrease in aft-end heat leak of 100 to 150 Btu per hour for the various vehicle orientations.

2. Airlock/S-IVB Interface Thermal Model

The thermal model, including internal radiation, was completed, and temperatures were obtained for the on-pad condition with worst-case, on-pad environment. This model indicates a tunnel extension bellows temperature of -130°F. The minimum required aft Airlock compartment temperature is -20°F. Two ways to increase the bellows temperature seem feasible: redesign S-IVB hatch to include low conductivity material and add heaters to bellows. Re-investigation of the Airlock minimum temperatures is planned.

3. Active Thermal Control System Study

The addition of four cabin heat exchangers in the Airlock below the aft hatch is feasible and will adequately remove the 2,500 Btu per hour (design criteria) heat load. Studies show that the thermal curtain can be deleted except for the impact upon warmup of the tank hardware. Radiant lamps will be needed to complete the warmup. Additional studies are required to define their power magnitude and location.

4. Propellant Tank Dynamic Testing

The proposed propellant tank for the Orbital Workshop Auxiliary Propulsion System successfully completed dynamic testing. After all testing was completed the leakage rate of the metal bellows was $3 \times 10^{-9}$ sccs of gaseous helium, which is within the specification limits.

5. Cryogenic Reliquefaction Compressor

Testing of this compressor was suspended because of severe scoring of the piston rod, retainers, and retainer seals, which resulted in damage to the piston seals. A redesign of the compressor is expected before further tests are performed.

6. Negative Beta (β) Impact

Studies were completed to assess the impact of -β attitudes with the S-IVB engine facing away from the earth sun line. These studies show that aft end losses will result in approximately 3.0 kW heater power requirements, 1.14 greater than the requested 1.86 kW. Previous recommendations to rotate the AAP-1/2 assembly 180°, S-IVB engine facing earth-sun line, will not increase the requested 1.86 kW value.

7. Activation Transients

Studies were performed to establish warmup characteristics of the orbital workshop during the period prior and subsequent to AAP-1 docking. The attitude considered was X-POP, with the Z axis solar fixed. As anticipated, a +53 beta angle orientation with minimum heating constants warms up slower than the corresponding conditions at a beta angle of 0-degrees. Internal surfaces will warm up to greater than -150°F by 18 hours after propellant venting. Internal temperatures at initial astronaut entry (60 hours after liftoff) are predicted to be approximately 0°F. Warmup of the walls to values for shirt-sleeve occupancy requires the installation and activation of the fans and the atmosphere heaters.

8. Solar Array Temperatures

Analyses to establish the refined solar array temperatures for a beta angle of +53, -53, and 0 degrees were completed. Results show that the maximum and minimum temperatures to be encountered are 104°F and -68°F, respectively. These values are well within the specified allowable range of -87°F to 230°F.

9. Cluster Humidity Model

A preliminary investigation of the dew-point temperatures in the cluster using one condensing heat exchanger in the Airlock Module and one in the Structural Transition Section was completed. This study indicates that the dew-point temperature gradient in the cluster is approximately 5°F. The maximum variation of the dew-point temperature for a particular element over a typical 24-hour day is ±2.5°F related to an average temperature of 46°F (specific humidity = .0184). This study

must be revised to consider the updated condensation characteristics of the condensing heat exchangers and the water generation capabilities of the astronauts while performing their various time-lined tasks.

10. Fan Fails Life Test

A bearing in the fan used in the OWS/MDA and Airlock failed during life test. The fan had 462 hours of vacuum storage (non-operating) and 1121 hours operation in a pure $O_2$ environment at 5 psia. The cause of the failure is attributed to inadequate lubrication. An improved lubricant and/or bearing are being investigated as possible solutions.

## SATURN V

### I. S-IC Stage

#### A. F-1 Engine

1. R&D Engine Tests at Edwards Field Laboratory (EFL)

Thirty-two tests were conducted, and a total duration of 4,318.7 seconds was accumulated. Approximately 22 of these tests were full-duration runs (150 seconds or more). One test was terminated prematurely when the turbine inlet temperature indication exceeded the redline value.

2. Engine and Turbopump POGO Testing at MSFC

Five F-1 engine and four F-1 turbopump tests were conducted to optimize the operating mode of the prevalve accumulator and evaluate the first and second LOX feedline modes using an upstream pulser. Data obtained in the operating mode studies established predictable operating methods for the prevalve accumulator. The four turbopump tests were conducted to evaluate the LOX feedline second mode. Neither upstream nor downstream pulsing on the engine and turbopump stand generated data which reliably establish the second feedline mode. These tests are being evaluated.

3. LOX Redline Temperature for F-1 Ignition

The engine contractor's LOX redline temperature for F-1 engine ignition is -275°F at station 190 (90 inches above LOX pump inlet). However, this redline temperature is currently checked at T-187 seconds in the countdown sequence. With this procedure, an unknown malfunction could cause this temperature to increase after T-187 seconds,

resulting in ignition temperatures that exceed redline values. This temperature increase could be as much as 3 °F before ignition. To assure meeting the engine start conditions, the redline was changed to verify LOX suction line temperatures below -278 °F at T-187 seconds.

B. Instrumentation Requirements

Instrumentation requirements and telemetry channel assignments were completed for AS-503. A retrorocket chamber pressure measurement was inadvertently deleted from the onboard tape recorder. Reinstatement was requested. The new position switch for the LOX vent valves will not be ready for AS-503, so the present switches will be disconnected. New check valves for the LOX and fuel prepressurization system will not be available until AS-504. These check valves leaked on AS-502 and had to be replaced several times. The interlock that was requested for the LOX dome purge system was rejected; therefore, the redline will have to remain in effect. A new prepresurization scheme was developed for S-IC-504 and subsequent.

C. POGO Investigation

The helium-charged LOX prevalve accumulators (PVA) on five lines are recommended as the POGO solution. The PVA provides vehicle stability margin greater than the helium injection for all conditions investigated. The vehicle stability criteria are satisfied with a system that has no single-point failures. The accumulators are filled to 100 percent at approximately eleven minutes before ignition. LOX tank pressurization decreases the volume to approximately 80 percent at ignition. The helium replenish system initiates at liftoff to assure that the PVA volume is 100 percent during flight.

Investigations are being directed toward the evaluation of the second LOX column mode, verification of the fuel pump compliance, and experimental verification of the LOX and fuel transfer functions. Emphasis is not directed to an evaluation of the structural loads expected with the POGO solution. The thrust perturbation resulting from helium "burping" from the outboard PVA at inboard engine cutoff is being evaluated.

D. Propulsion System Flight Performance Predictions

A special propulsion performance prediction for Saturn vehicle AS-506 was completed for establishment of a payload baseline case. This baseline case will be used to provide a more efficient payload control for the AS-506 mission.

E. Failure of Vent Valve Position Switches Investigated

The failure of the position switch in AS-502 vent valve during CDDT was traced to failure of resistance weld of an actuating pin to the sine (spring) blade. The pin broke off and shorted the electrical power to ground through the switch case. To correct the problem, the pin was riveted to the sine blade. This fix was tested for strength and the switch requalified at $LH_2$ temperatures and life cycle.

II. S-II Stage

A. J-2 Engine

1. R&D Testing at SSFL

Thirty-nine tests were conducted, and a total of 4083 seconds was accumulated. Four tests were full-duration runs (500 seconds or more). All of the tests ran for the planned duration.

2. Engine Testing at AEDC

Thirteen hot firings were completed on engine J-2036-1. Nine of the firings were worst case model specification start limits for the S-II engine configuration. The remaining four tests were worst case S-IVB tests, and these were the first S-IVB tests to be conducted on this engine sample. Two of the tests were cutoff early by engine safety devices. The first was due to a failure of the ASI ignition detector probe to detect ignition. The second occurred during the 80-minute restart test when the GG temperature exceeded the limit because the crossover duct temperature was about 10°F above the limit.

3. J-2S Engine Program

Testing totaled 320 seconds of J-2S engine operation, 68 seconds of which were at the 265K thrust level.

B. S-II-5 Acceptance Firing

The unsuccessful attempt to acceptance test S-II-5 was monitored and analyzed. During the special tests conducted in the countdown preceding the acceptance firing, several anomalies occurred that resulted in the scrubbing of the test. The special test of the $LH_2$ tank vent valves revealed that the No. 2 $LH_2$ vent valve did not crack in either the low or high relief modes. Also, during the common bulkhead special test, both valves failed to open upon command. The decision was made to detank and reschedule. Post-test investigation revealed that the No. 2 $LH_2$ tank vent valve reference line was connected into the hazardous gas vent system. Since a vacuum was never applied to

the sensing port of this vent valve, the delta pressure was not sufficient to cause relief. It was also discovered that an 0.08-inch diameter orifice was installed downstream of both the regular and actuation supply measurement in the 750 psig supply line. Tests are being conducted to determine what the actuation pressure at the vent valves would be in this configuration.

C. LOX Depletion Cutoff

A modification is being investigated that would allow S-II LOX depletion; that is, mainstage OK cutoff on S-II-6 and subs for an approximate 900-pound payload gain. The following plan was proposed and is being reviewed:

1. S-II-4 - Implement one-second time delay between LOX cutoff sensor uncover and cutoff signal.

2. S-II-5 - Implement 1.5-second time delay, which should closely approach mainstage OK cutoff.

3. S-II-6 - Deactivate LOX depletion cutoff sensors and rely on mainstage OK cutoff of all engines.

The review will also consider (but is not limited to) the following:

1. Requirements for additional ground engine testing, single and/or cluster.

2. Methods for engine shut-down (single engine or a "one-out, all-out" method).

D. S-II-503 Fuel Tank Vent Failure Analysis During Burn

The Flight Information and Operation Report (FIOR) identified an S-II fuel vent failure as a possible catastrophic condition requiring an astronaut abort mode. A catastrophic condition exists when the ullage pressure drops to the minimum allowable based on 100 feet NPSH. The highest ullage pressure decay rate exists for a vent failure during the ignition transient. There are approximately 16 seconds from the failure to the minimum allowable ullage pressure (100 feet NPSH) during this period. This information will be used in the Flight Mission Rules.

III. S-IVB Stage

A. APS Extended Hold Test Program

Test Module No. 1 completed 75 days of extended hold at

SACTO. Six burp firings were conducted during this period at intervals of 15 days. Significant degradation in chamber pressure was observed on engines 1 and 3 during the last three burp firings. To obtain an additional data point on the engine performance degradation problem, the contractor will induce performance degradation on engine 2 by burp firing that engine alone with the module rotated 90 degrees.

B. Continuous Vent System Thrust Unbalance

Module I of the S-IVB/501 attitude control system used an excessive amount of propellant during orbital coast. A continuous vent system thrust unbalance may have caused excessive ACS activity. The maximum thrust unbalance was determined to be 1.01 $lb_f$ when the vents were open initially at orbital insertion.

The results of this study will be used in a reconstruction of the AS-501 orbital coast to determine if the excessive Attitude Control System propellant usage was caused by continuous vent system thrust unbalance.

C. SA-501 APS Anomaly Testing

A series of tests was conducted on the APS engines to determine the effect of short-duration firings followed by several days of hold at sea level conditions. Engine chamber pressure decay was verified in several of the tests, and one engine was sectioned and examined to determine the cause of the decay. The injector oxidizer passages contained particles that appeared to be chemical in nature. The effect of these particles on oxidizer flow is assumed to be the primary cause of the Pc decay. Further testing is being conducted on an injector to isolate the flow restriction.

D. Propulsion Predictions

Propulsion performance predictions for S-IVB stages AS-504 and AS-505 are currently being generated. The prediction for AS-504 consists of two referenced nominal cases, one for a two-orbit injection time and one for a three-orbit injection time. The prediction for AS-505 is comprised of a nominal case plus eight dispersion cases. Also, additional engine-out malfunction cases for AS-504 and AS-505 were requested.

E. S-IVB-506 Acceptance Firing

The S-IVB-506 acceptance firing was completed successfully. This is the first stage firing of the restartable burner. Two successful burner firings were performed; the first was a normal firing, and the second demonstrated restart of the burner. The firing was for the full

duration (445.2 seconds), and cutoff was by LOX depletion. Cold helium leak checks were performed before and after the firing. No leaks were noted. The cold helium system incorporated the latest teflon-coated cono-seals throughout, and the modifications seem to be satisfactory.

F. Modified Accumulator Reservoir Assembly Verification Testing

This assembly was modified and tested because of low inlet pressure problems with the hydraulic gimbaling system pump. Two Quad-rings replaced two O-rings in the piston seals and reservoir piston springs and retainers were added. Testing was completed successfully.

G. Fuel Tank Vent Failure Analysis During Burn

Oxidizer and fuel tank vent failures (open) were identified on the upper stages of the Saturn IB and Saturn V vehicles as possible abort conditions. This information will be inserted in the flight mission rules. The $LH_2$ tank vent failure in the full-open position was analyzed to determine ullage pressure decay rates at various times during the burn. The minimum allowable ullage pressure was based on 100 feet NPSH, which is considered to be the minimum for noncatastrophic conditions. The most critical time for vent failure is during the ignition transient where there are only 14 seconds until the minimum allowable pressure for the S-IVB-205 and approximately five seconds on the S-IVB-503 (first burn).

## SPECIAL STUDIES

I. Apollo Telescope Mount (ATM)

A. ATM Radiator Life Test

This test program is being conducted to determine the effect of long-duration operation with methanol/water on the phenolic bond of the radiator panel. After 240 hours of operation, the radiator panel leak rate was determined to be less than $1 \times 10^{-7}$ sccs. Testing has continued, and a total of 720 hours of running time were successfully completed.

B. Quadrant IV Thermal Test

Data reduction for the first seven test runs is complete with the exception of the power data from two tests. A second attempt to conduct tests with stand-off heaters was aborted when the data acquisition system failed. Partial data recovered from the first attempt revealed thermal performance varied adversely from expectations. The effect

was subsequently verified by the Chrysler analytical models. A third run with stand-off heaters is complete using an alternate data system.

C. Quarter Rack Test

The test plan was updated to the present level of available information. A data reduction computer program was initiated. The IR lamp layout and cage design for Position II was completed; layout design of the remaining three positions is continuing. The 200 thermocouples were completed. Fabrication and interfacing of mounting panels, thermal shields, and CMG mounts is 70 percent complete. Fabrication of the test support structure was started after completion of the design.

D. Experiment Package Test

A rough draft of the test plan was reviewed. The final copy should be released during the first half of August. The AS&E Telescope TMU was received. The canister cooling system for the Experiment Package Test was defined and the components are being located. Feasibility of using a rack simulator instead of IR lamp arrays over the rack-enclosed portion of the canister is being studied.

II. Multiple Docking Adapter (MDA)

A. MDA Environmental Control System (ECS) Ducts

An analysis of the current MDA ECS duct configuration was performed to evaluate the capability of this ducting system to meet specified design requirements. Results of this analysis are:

1. The main ECS ducts from the cabin heat exchangers have pressure losses that exceed the design requirements, primarily due to the 4-inch diameter line which penetrates the structural ring at the MDA/STS interface. This increased duct loss does not appear to have a significant effect on the ECS overall performance, since the MDA duct pressure loss is only 6 percent of the total system pressure loss (major pressure losses are in the heat exchanger).

2. The ECS flex ducts serving the docking ports cannot deliver the 150 cfm minimum required flow rate. Current estimated flow rates are 129 cfm to the Lunar Module (LM) and 132 cfm to the Command Service Module (CSM). The primary cause of these reduced flow rates is the loss of fan performance with reduced voltage to the fan motor. Minimum fan motor voltage was identified as 24 volts considering the AL distribution bus voltage of 28 $\pm$2 volts and allowable line losses of 2 volts maximum. MSC was requested to determine the impact of these reduced flow rates on the LM environment.

B. Inflight Venting

An analysis was performed to determine the feasibility of maintaining a 3.0 psid MDA/SLA differential pressure during the first 10 seconds of flight to satisfy a structural requirement and to determine the accuracy which a 5 psia MDA lockup pressure can be achieved. With the current 7.0 $in.^2$ MDA vent area, the following performance was determined:

1. If MDA vent valves accidentally open at liftoff, an MDA liftoff pressure of 5 psig is required to meet the structural requirement of 3 psid (minimum) during the first 10 seconds of flight.

2. MDA/SLA differential pressures do not exceed allowable limits with MDA liftoff pressures $\leqq$ 5.0 psig and MDA vents open no later than 10 seconds after liftoff.

3. The MDA vent valves can be programmed to close approximately 100 seconds after liftoff to achieve an MDA lockup pressure of $5 \pm 1/2$ psia independent of liftoff pressure.

III. Zero Leakage Projects

A. Vibration of the Insulation Purge Test Panel

A test panel with nylon tube fittings successfully completed vibration test in three axis. There was no visible damage to the aluminum tubing or the nylon fittings.

B. Boss Seal Connections

An O-ring of silicone rubber compond 11207 at 50 psig helium pressure displayed leakage of $13.0 \times 10^{-7}$ sccs at +130 °F and -130 °F, respectively. An O-ring of silicone rubber compound 11205 displayed leakage of $6.8 \times 10^{-7}$ sccs and $3.1 \times 10^{-10}$ sccs at +130 °F, respectively.

IV. Uprated Saturn V Launch Facilities

The program to evaluate the effects of strap-on solid motors on launch facilities through the use of scale motors was continued. It was determined that part of the ignition problems may have been caused by defective firing circuits. Replacement circuits improved the firing capability to the extent that previously rejected initiators fired.

V. Slush Study

The experimental portion of the slush technology program is to verify the feasibility of the recirculation technique for loading and upgrading of flight-type tankage. The test tank is a 41.5-inch diameter sphere with high performance insulation and enclosed in a vacuum chamber to simulate flight pressure transients and propellant heating rates. The initial tests were unsuccessful due to excessive heat input primarily in the valve, duct, etc. The system was modified to provide adequate vacuum in the ducts and insulation around the valve, bayonet fitting and pressurization lines, and additional tests are planned.

VI. Low-g Boiling Heat Transfer

The various components necessary for the non-cryogenic package are being assembled. Nucleate boiling around the edge of the heater surface continues to be a problem. The modified heater design uses a silicone 140 coating of the epoxy-heater surface joint. This coating has been reasonably successful in reducing the number of nucleation sites. Non-cryogenic tests are being planned.

## ADVANCED PROPULSION AND TECHNOLOGY

I. Small Engine Evaluation Program

Tests were conducted on a Hamilton Standard 100-pound thrust monopropellant engine. A total run time of 310 seconds was obtained during both pulsing and steady-state operation. The engine operated normally except for the Hydraulics Research (HR) engine valve. The bipropellant torque motor valve exhibited very poor opening response with the nominal opening time being 32 milliseconds. As a result, the engine failed to fire during the 30 MS pulses. Each of the two HR valves were subsequently tested to determine their operating characteristics. At valve inlet pressures above 350 psia the valves intermittently failed to open when supplied with 1.0 amp 26.5 volt power. At lower pressures the valves occasionally "chattered" after opening. Investigation of this problem is continuing. The engine vendor is analyzing the temperature data and inspecting the engine in an attempt to determine the cause of failure.

II. Advanced Engine Aerospike Experimental Investigation

Water flow tests of the injector revealed a significantly higher propellant flow in three compartments which had some erosion during the previous test series. An estimated local mixture ratio of 10 resulted

from this increased flow. Hardware inspection revealed errors in insertion depth of pins in the LOX downcomers allowing higher than planned LOX flow in these passages. The pins were placed in the injector to add flow resistance which successfully reduced combustion oscillations in the chamber. New pins have been inserted and propellant flows balanced. The baffle coolant circuit was reorificed to increase baffle coolant flow from 23 to 30 percent of the total hydrogen flow. This will increase the baffle cooling margin to allow tests approaching a mixture ratio of 5.

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Note: Following are the missing pages.
Page Nos. – i, ii, 34, 52.